DOCUMENT RESUME

ED 419 688 SE 061 406

AUTHOR	O'Connor, Vincent F., Ed.; Hynes, Michael C., Ed.
TITLE	Mission Mathematics: Linking Aerospace and the NCTM Standards. Grades 5-8.
INSTITUTION	National Council of Teachers of Mathematics, Inc., Reston, VA.; National Aeronautics and Space Administration, Washington, DC.
ISBN	ISBN-0-87353-435-2
PUB DATE	1997-00-00
NOTE	157p.
AVAILABLE FROM	National Council of Teachers of Mathematics, 1906 Association Drive, Reston, VA 20191-1593 ($19.95).
PUB TYPE	Books (010) -- Guides - Classroom - Teacher (052)
EDRS PRICE	EDRS Price MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Earth Science; Educational Resources; *Integrated Activities; Intermediate Grades; Junior High Schools; Lesson Plans; *Mathematics Education; Middle Schools; Science Education; *Space Sciences
IDENTIFIERS	NCTM Curriculum and Evaluation Standards

ABSTRACT

This book is a collaborative project between the National Aeronautics Space Administration (NASA) and the National Council of Teachers of Mathematics (NCTM). It has two complementary goals: to provide classroom-tested lessons that effectively model the vision of the NCTM Standards and to focus on the exciting problems that arise out of NASA's activities. The lessons contained within this document are couched in an aerospace setting to motivate students to become involved with and connected to mathematical concepts, skills, and applications. Activities and lessons can be used independently to show how mathematics is used in the space industry. Many lessons are linked to form in-depth investigations that can be used in a variety of ways. The investigations are designed to become potential replacement units for parts of the present school curriculum. Chapters include: (1) "Lunar Exploration"; (2) "How Big Is Our Neighborhood?"; (3) "The Speed of Light"; (4) "Aeronautics"; and (5) "Mission To Planet Earth". (ASK)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE AND IN ELECTRONIC MEDIA FOR ERIC COLLECTION SUBSCRIBERS ONLY HAS BEEN GRANTED BY

J. Carpenter

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

2A

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

ED 419 688

Mission Mathematics

5–8

A NASA/NCTM Project

BEST COPY AVAILABLE

Mission Mathematics

Grades 5–8

Vincent F. O'Connor
Michael C. Hynes

Contributors
Conni Blomberg
Michael Endress
John Kramer
Donna J. Moss
David F. Ortega
James E. Pratt
Deborah A. Shearer
Brad R. Thode

Project Director
Michael C. Hynes

PUBLISHED IN COOPERATION WITH
THE NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION

NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS

Copyright © 1997 by
THE NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS, INC.
1906 Association Drive, Reston, VA 20191-1593
All rights reserved

Library of Congress Cataloging-in-Publication Data

Mission mathematics : grades 5–8 / [edited by] Vincent F. O'Connor, Michael C. Hynes ; contributors, Conni Blomberg ... [et al.] ; project director, Michael C. Hynes.
p. cm.
"Published in cooperation with the National Aeronautics and Space Administration."
Includes bibliographical references.
ISBN 0-87353-435-2 (pbk.)
1. Mathematics—Study and teaching (Middle school) I. O'Connor, Vincent F. II. Hynes, Michael C., 1941– . III. Blomberg, Conni. IV. United States. National Aeronautics and Space Administration.
QA11.M547 1997
372.7'044—dc21 97-42145
CIP

Cover photograph by Dominque Dierick and Els Jacobs, all rights reserved.

Text photographs, unless otherwise credited, are courtesy of NASA.

The publications of the National Council of Teachers of Mathematics present a variety of viewpoints. The views expressed or implied in this publication, unless otherwise noted, should not be interpreted as official positions of the Council.

PRINTED IN THE UNITED STATES OF AMERICA

CONTENTS

Foreword . . . . . ***iv***

Preface . . . . . ***v***

Lunar Exploration ***1***

Module: Space Rocks 3

Lesson 1: How Big Are the Rocks? 5

Lesson 2: How Hard Are the Rocks? 9

Lesson 3: Where Are the Rocks? 11

How Big Is Our Neighborhood? ***17***

Module: Take a Spin 19

Lesson 1: Orbit Lab 21

Lesson 2: A Planetary System 25

Lesson 3: Our Solar System 29

Lesson 4: 1000-Yard Solar System 34

The Speed of Light ***47***

Module: How Far Can I Go in 8 Seconds? 49

Lesson 1: Finding Our Top Speed 51

Lesson 2: An 8-Second Trip 54

Lesson 3: Travel in the Solar System 60

Aeronautics ***69***

Module: Air Olympics 71

Lesson 1: Our First Paper Airplanes 73

Lesson 2: Testing Conjectures about the Design of Paper Airplanes 76

Lesson 3: Organizing and Analyzing Test-Flight Data 78

Lesson 4: Wind-Tunnel Tests 81

Lesson 5: Defining the Events 84

Lesson 6: The Air Olympics 86

Lesson 7: Debriefing 88

Mission to Planet Earth ***109***

Lesson 1: Polar Ice 111

Lesson 2: Orbiting Satellites 114

Lesson 3: Tracking Migrating Whales 117

Appendix: NASA Resources for Educators ***134***

References ***136***

FOREWORD

Mission Mathematics: Linking Aerospace and the NCTM Standards is a collaborative project of the National Aeronautics and Space Administration (NASA) and the National Council of Teachers of Mathematics (NCTM). The vision of Frank Owens, director of educational programs for NASA, and James Gates, executive director of NCTM at the time this project was conceived, inspired this unprecedented effort to link the science of aeronautics to the standards NCTM has developed for all aspects of mathematics education. The guidance of the project was entrusted to Pamela Mountjoy (NASA), Cyndy Rosso (NCTM), and Marilyn Hala (NCTM). Their support and expertise have facilitated the completion of the project, and their contributions have added immensely to the quality of this product.

The middle school book is the bridge between the elementary and the high school book. In that sense it mirrors the reality of middle school teaching. Continually, teachers strive to capture the best of two worlds: the nurturing, collaborative environment of elementary education and the subject-matter-dominated high school curriculum. Vince O'Connor, the middle school editor, has guided the middle school writing team through the perils and pitfalls of following either the elementary or high school philosophy to the exclusion of the other. The writing team has walked that narrow ledge and succeeded. They use many techniques from elementary mathematics teaching while focusing on meaningful content. However, the content is presented in the context of aerospace. The middle school writing team has worked diligently to use aerospace to create interesting modules that will assist students in becoming collaborative, lifelong learners of mathematics. The middle school writing team consists of Conni Blomberg, Michael Endress, John Kramer, Donna Moss, David Ortega, James Pratt, Deborah Shearer, and Brad Thode.

The development of the activities for this project included a pilot testing of activities in classrooms throughout the nation. NCTM made a call for teacher-participants in this phase of the project in the *NCTM News Bulletin*. We could never have anticipated the response from classroom teachers. Our e-mail was overloaded and the regular mail always seemed to have another offer to volunteer time for the project. Many teachers phoned us to follow up on their earlier correspondence. Clearly, our teachers are interested in using the context of aerospace to improve learning in their classrooms. Unfortunately, budget constraints in the project forced us to select only a few teacher-participants from the volunteers. The cost of duplicating pilot materials and the postage to deliver classroom sets to teachers prohibited us from using everyone who volunteered. For the pilot, classrooms were selected to give us a broad geographical, ethnic, and socioeconomic view of the effectiveness of the lessons. The large number of volunteers allowed us the opportunity to do this well. To those teachers who participated by sending feedback from their classroom experience with draft activities, thank you. Your feedback allowed the writing teams to make the activities more effective for children. Also, we thank all of you who volunteered to assist in the project. This type of spirit makes the teaching profession extremely rewarding.

As can be seen, this book was the product of many hands and minds. The collaborative effort of many people made this important project a reality. Thank you all.

Michael C. Hynes, Project Director

PREFACE

◆ *What do you think of when you hear* NASA?

You probably think of the Space Shuttle and astronauts. Although those elements are important to the NASA mission, they barely scratch the surface of what NASA does. A major purpose in producing the lessons in this book was to acquaint students with NASA activities related to aeronautics, space science, and human exploration and development of space and with NASA's Mission to Planet Earth.

◆ *What do you think of when you hear* mathematics standards?

You probably think of the NCTM *Curriculum and Evaluation Standards for School Mathematics* (1989). The work done in describing a true vision of mathematics for the twenty-first century has earned the *Standards* document a place at the center of educational progress and has made that document a model for other subject areas. Today, it is just one of a trilogy of *Standards* documents produced by NCTM. The addition of the *Professional Standards for Teaching Mathematics* (1991) and the *Assessment Standards for School Mathematics* (1995) has formed a coherent vision for mathematics curriculum, instruction, and assessment that is challenging the education community to meet the mathematical needs of all students—students who will live their lives in an increasingly technological world.

◆ *So, why was Mission Mathematics produced?*

Mission Mathematics arose out of two complementary goals: (1) to provide classroom-tested lessons that effectively model the vision of the NCTM *Standards* documents and (2) to focus on the exciting problems that arise out of NASA's activities.

The lessons in *Mission Mathematics: Grades 5–8* are couched in aerospace settings that motivate students to become involved with, and connected to, mathematical concepts, skills, and applications. These research settings construct a rich base for building students' interest and "buy-in," which is so important in engaging all students in the learning activities. The focus on NASA in these research settings also contributes to the students' career education and helps develop connections between mathematics and the real world.

◆ *What design features have been built into these materials?*

Thematic Modules

Many of the middle-grades materials are built around investigations into NASA's activities. Thus, instead of being a collection of independent, one-day lessons, these materials consist of thematic units that may span several weeks. In line with curriculum planning for many middle schools, these modules afford multiple opportunities to connect mathematics to other disciplines. Many of the lessons, however, can be used independently. Some lessons have multiple activities that may require more than one class period.

Discourse

The *Standards* documents describe a learning environment that promotes rich discourse among students. *Mission Mathematics: Grades 5–8* was designed to optimize student-to-student discourse through the formation of student teams that engage in discovery, decision making, and problem solving. Numerous opportunities are also presented for teams to develop and present their findings in debriefing sessions to the entire class.

Assessment

In keeping with the vision of the *Standards* documents, the modules in *Mission Mathematics: Grades 5–8* offer multiple opportunities for teachers to monitor the progress of their students through work products, observation, log books or journals, and discourse. Students are encouraged to make daily entries into log books to document their experiences during their "mission." In most modules, the students complete other work products, which provide tangible evidence of their achievements.

The Formation of Student Teams

Mission Mathematics: Grades 5–8 lessons require the formation of student teams. One reason for this approach is to maximize the active participation of all students in the learning process. A second reason—perhaps more important to the authors—is to be true to the way that NASA does business. Cooperative teams are the hallmark of virtually every successful business today. NASA is no exception and may even be a model of how teams get involved at every level in improving the chances for success on their missions. Middle school students are developmentally ready for working together in small groups, but they may not have had the experience of working cooperatively with their peers. Since traditional textbooks have been designed to fit the model of individual learners working alone, they may not lend themselves to introducing and developing cooperative learning skills with middle school students. *Mission Mathematics: Grades 5–8* modules may be especially effective in helping the middle school teacher form and promote the development of cooperative teams.

Mathematical Content

Each lesson in *Mission Mathematics: Grades 5–8* correlates with the content standards for grades 5–8 as found in the NCTM *Curriculum and Evaluation Standards*. However, it is assumed that these materials are being used in conjunction with a basal series. Thus, they do not attempt to duplicate the expository or practice materials that are normally contained in the basal text. Rather, it is expected that Mission Mathematics lessons will be blended with other sources to give students explanations of ideas or practice with skills that are introduced or used in these lessons.

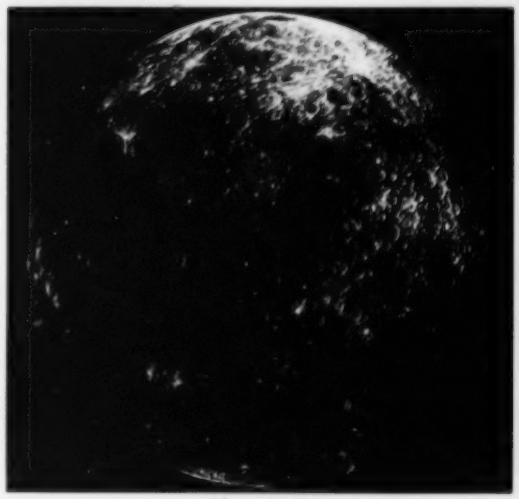
◆ *How do I use these materials?*

The Mission Mathematics lessons and activities are natural for motivating middle school students to study mathematics. Learning in a meaningful context is important for all students and perhaps more so for middle school students. The activities and lessons can be used independently to show a use of mathematics in the space industry. Many of the lessons are linked to form in-depth investigations that can be used in flexible ways. The investigations can become replacement units for parts of the present school curriculum. If teachers wish to use the materials in this way, the whole unit can be done at once or the lessons can be used at regular intervals (e.g., every Monday) in a regular unit of study in the mathematics curriculum. These investigations are ideal for schools that have instituted any form of block scheduling in mathematics. The longer time periods of block scheduling allow for active participation in activities, group work, data gathering, and journal writing. Regardless of the organization of the school and the classroom, the activities, lessons, and investigations in *Mission Mathematics: Grades 5–8* will prove useful in helping middle school students learn mathematics.

LUNAR EXPLORATION

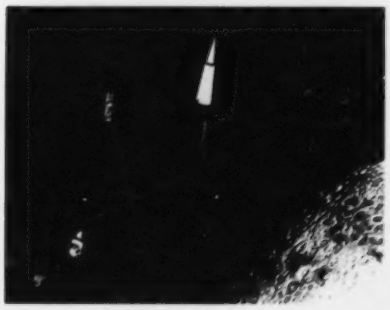
The National Aeronautics and Space Administration has a strong commitment to human exploration and development of space. This endeavor includes fostering commercial space opportunities. The possibility of mining on the Moon is not so far-fetched. Moon rocks returned from the Apollo missions and from other data-collection techniques have shown that important minerals exist on the Moon.

One important resource on the moon is He^3, an isotope of helium. He^3 may become significant in producing electricity on Earth. Since helium is a relatively safe gas, He^3 is thought to be important to the development, on a commercial scale, of fusion as a source of energy. Some He^3 is available on Earth, but the sources are nonrenewable; that is, we have a small and easily exhaustible supply.



The Moon

The good news is that scientists have estimated that tons of He^3 have been deposited in the lunar soil by solar winds. The mining of He^3 would be feasible from an availability perspective. Although the Shuttle is not designed to go to the Moon, we can use our knowledge of the orbiter to think about the value of mining He^3 on the lunar surface. It is estimated that a cargo bay as large as the one in the Shuttle orbiter would hold enough He^3 to produce enough energy through fusion to supply all of the United States with energy for a year. Also, one hundred tons of He^3 could supply the world with energy for a year. With an estimated one million or more tons of He^3 on the Moon, there is enough to provide energy for ten thousand years. Can you imagine how valuable a cargo bay full of He^3 would be? Certainly it will be worth our effort to make lunar mining a reality.

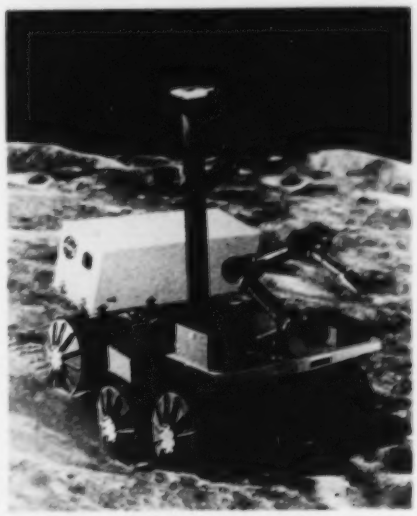


Lunar Prospector

The existence on the Moon of He^3 and other minerals gives us reason to begin exploring this nearest of our celestial neighbors. The *Lunar Prospector* is a spacecraft designed for a "fly over" mission to map the surface of the Moon, collect data about its magnetic fields and gravity fields, and monitor gas releases from

the Moon. The data collected will give scientists clues related to the composition of the Moon. This information will improve our current understanding of the origin of the Moon, its evolution, its current state, and the nature of its resources.

The Lunar Prospector mission is not the only effort to collect data about the Moon. There will be concurrent fly-over missions by other countries and agencies, subsequent probes of the surface of the Moon, and robotic explorations of the Moon. All the data from these missions will be shared to prepare for safe and productive human exploration of the Moon.



An unmanned Lunar Rover

If all scientific efforts continue to be successful, we could see our first extraterrestrial outpost on the Moon as early as 2020. This outpost could be used for the direct exploration of the Moon as well as for the support system for commercial ventures related to the Moon. Scientists could use the base for long-range observations of Earth and for astronomical observations within the the solar system and beyond—the stars and the galaxies of the universe.

An artist's rendition of transportation to a permanently manned outpost on the Moon

Mining on the Moon is not far-fetched. It is feasible, and it is planned. Mathematics is playing an important role in the effort to make moon mining a reality. The following investigation has been developed particularly for middle school students by using the natural motivational aspect of space travel and exploration. The mathematics selected for study represents appropriate concepts for middle school students, and the activities require thought and actions that will be a part of moon mining.

MODULE
SPACE ROCKS

Module Mission

To use measurement and descriptive terms to describe the attributes of "space rocks"

To apply direct and indirect means of measuring irregular objects

To map a scientific site for geological research by using coordinate geometry

NCTM Mathematics Standards

Algebra

Geometry

Statistics

Measurement

Number and Number Relationships

Through NASA's research, we continue to learn exciting things about our celestial neighbors. NASA's scientists are continually examining data related to the composition of the Moon and the planets. Helping students understand the roles of scientists and putting them in those roles tend to improve their dispositions toward learning. In this lesson, the topic of the nature of other celestial bodies motivates students to assume the role of geologists studying rocks from the Moon and the planets. Many students will know that lunar rocks have been brought to Earth by Apollo astronauts. They may have seen samples of these rocks exhibited at a NASA research center or at a museum.

More recently, rocks believed to be meteorites from the surface of Mars have increased the attention given to the scientific work of NASA geologists. Evidence found in the rocks raises the possibility that the environment of Mars may once have been hospitable to some forms of life.

On 4 July 1997, NASA's *Pathfinder* landed on Mars and released the six-wheeled robotic rover Sojourner. Sojourner is equipped with a scientific apparatus for conducting on-site analyses of Martian soil and rocks. This on-site capability allows scientists to study as many different rocks and types of soil as possible for as long as the rover and its instrument function. The Pathfinder mission found evidence to support the theory that water, which is necessary to life, once existed on Mars.

The Pathfinder mission will be followed by a series of robotic explorations of Mars to be launched at twenty-six-month intervals through 2005 and possibly beyond. The first of the explorers in the Mars Surveyor Program, *Mars Global Surveyor*, is scheduled to enter an orbit around Mars in September 1997. The polar-orbiting spacecraft is designed to produce global maps of the surface topography and the distribution of minerals on Mars and to monitor the Martian weather.

An artist's rendering of the robotic rover, Sojourner, from the Mars Pathfinder

INTRODUCTION

This module has three lessons appropriate for all grade levels in middle school. All involve a high degree of student participation in hands-on activities. Thus, the amount of time for completing the module will vary; probably six to nine class periods will be needed. If some of the mathematics required for the module must be taught, the time required may exceed nine class periods. These lessons need not be presented on consecutive days. They can be interspersed among other mathematics lessons over a longer time. The "Space Rocks" lessons are as follows:

- "How Big Are the Rocks?" Students describe and catalog "space rocks" using the notion of attributes. They learn to use indirect measurement and approximations to measure some attributes of the rocks.

NCTM Teaching Standards:

Teachers should engage students in tasks that help them make connections and develop a coherent framework for mathematical ideas.

(NCTM 1991, p. 25)

BEST COPY AVAILABLE

- "How Hard Are the Rocks?" This lesson focuses on one of the attributes of minerals: hardness. Students learn about, and develop a scale of, hardness and apply it to their set of space rocks.
- "Where Are the Rocks?" Students play the role of scientists in the field who are creating a site map of a research area. Also, they use another mission team's data to re-create a research site by locating all rocks on the site.

The module requires a collection of rocks. To get a good variety, students may need to bring in interesting rocks they have already collected or that they find in their neighborhoods. If all rocks are collected from the same neighborhood, however, it is likely that few differences in their characteristics will be found. If possible, order at least one set of rock specimens from a science supply house, or ask a science teacher if the school has a geology kit.

CLOSING THE ACTIVITIES

NCTM Assessment Standards:
Verification of student knowledge should come from many sources.

Communicating mathematical ideas is one of the process goals of the *Standards* documents. Throughout this book, students are asked to write in mission log books. This form of journal writing can help students develop their communication skills related to mathematics. Sometimes students are asked to record vocabulary or their progress on an assignment. At other times, they are asked to reflect on what they have learned in the activity. All these assignments are important to mathematical learning. A log sheet for the "Space Rocks" module is included on page 14. Make copies of the log sheet so students can write about their learning after each activity and complete questions about the mathematics they used. The teacher may be able to document a student's learning from his or her comments in the log.

SPACE ROCKS LOG SHEET

An astronaut on the Moon

Date:

Mission Specialist's Name:

Team Name:

Members:

The things I did and the mathematics I used:

The things I found out and the mathematics I learned:

The things I wonder about and the mathematics I want to know about:

Another way for students to communicate their mathematical understanding from the unit is to develop a "mission patch" and a log-book cover for each unit. Students use their creative ideas to link the mathematics they are learning to the aeronautical themes of the units. At NASA, each astronaut team develops a patch that is unique to its mission. The NASA patches depicted at the end of this module can serve as models to help students design their own patches and log-book covers. Illustrating the cover of the log book can become an ongoing activity. When teachers become facilitators of students' learning as they operate in groups, some students complete their tasks before others do. Thus, some students will need additional worthwhile learning activities. The development of log-book covers is an example of a way to "sponge" time and extend opportunities for learning.

A picture of a small pan balance or a picture of a scientist in the field are common elements often found in patches for this unit. The inclusion of these items on the patch indicates what the students saw as important in the module. A great deal of reflection about their learning occurs when students are deciding what to include in their patches.

LESSON 1
HOW BIG ARE THE ROCKS?

Mission

To measure the weight, volume, and surface area of irregular objects to simulate examining rock specimens from other celestial bodies

Astronauts on the Apollo missions to the Moon returned with moon rocks. These rocks remain one of the treasures of the world. They are kept in a controlled environment, and only certified professionals have access to them. Scientists have analyzed them to catalog their characteristics, to determine their mineral content, and to examine them for fossil remains.

Moon rocks

More recently, scientists found some suggestions of the possibility of primitive life while examining the remains of meteorites believed to have come from Mars. This discovery has given new meaning to future unmanned probes of Mars. *Pathfinder* is one of the probes designed to roam around specified areas of the Martian landscape, examine soil samples and rocks, and analyze the composition of this material.

NCTM Mathematics Standards

Algebra

Measurement

Statistics (for the technology connection)

Technology Connection: ***The data from this lesson can be incorporated into a database, which allows students to sort the data according to attributes. Additionally, they can calculate mean measures for the collection.***

An LCD display panel lets the whole class participate in building the database. Students can identify the fields for the data and decide on the statistics important for summarizing the data.

PURPOSES

Students determine the important attributes of "space rocks." The attributes that are measurable are used to develop the students' understanding of measuring irregular shapes.

Students write about their experiences in this module in their mission log books, and each student develops a mission patch to illustrate what he or she has learned in the activities.

GETTING STARTED

Begin with a brainstorming session for the whole class. As in all such sessions, the teacher must accept all responses to the important question. Each response from students should be received as a genuine conjecture. After the initial brainstorming, the list of conjectures can be prioritized and the more plausible ones can be retained for further study.

The question for today is, "How have scientists got rock specimens from outer space to study in our laboratories?"

- Some students may know about the Apollo missions.
- A few students may remember reading about the Mars meteorites.
- Some will say that aliens brought them to us.
- Some will say that Space Shuttle astronauts brought them back as souvenirs.
- Some will say that we have no rocks from other celestial bodies.

NCTM Teaching Standards: ***The teacher of mathematics should orchestrate discourse by—***

- ***posing questions that elicit, engage, and challenge students' thinking;***
- ***listening carefully to students' ideas;***
- ***deciding what to pursue in depth from among the ideas that students bring up during discussion.***

(NCTM 1991, p. 35)

Many additional creative responses to this question will be offered. Accept and record all responses, then have students rank the items on the list from the most likely to the least likely. This is an opportunity to talk about the space program and the exploration of our solar system. It is important to emphasize the role of the Shuttle to remove any misconceptions that Shuttle astronauts visit the Moon or any of the planets.

Students can bring to class interesting rocks they have found in their yards or neighborhoods or on vacation trips. These can become part of the "space rocks" collection.

For the activities of this module, place the students into mission teams of four students. The members of the mission teams simulate the work of scientists who examine rocks from the Moon or one of the planets. They examine their "space rocks" and record on a data sheet the properties of the rocks.

Part A

GETTING STARTED

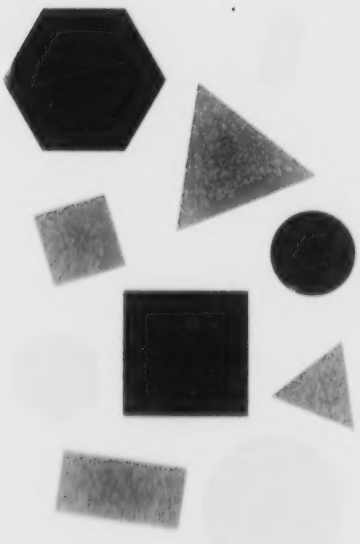
Materials: ***Log sheets; a rock collection; attribute blocks; sets of measuring instruments, including rulers, string, graduated cylinders, marked beakers, graph paper, balance scales, and standard masses; and small boxes***

Show the students the rock collection and compliment them for bringing in a wonderful collection of "space rocks." Tell them that very soon they will begin to study these rocks. But before studying unfamiliar "objects from space," the class will look at some familiar objects.

Show the class an attribute block. Talk about why it has that name. What are the attributes of the block? Each mission team should create a list of attributes and share the list with the whole class. The final class list will comprise typical attributes of color, size, shape, thickness, texture, weight, and so on.

Some of these attributes are measurable; some are just descriptive. Color is a descriptive term. Weight is measurable. Through class discussion, separate the list of attributes into a list of descriptive attributes and a list of measurable ones.

DEVELOPING THE ACTIVITY



Attribute blocks

Scientists expend a great deal of effort to determine the attributes of rocks. The rocks brought from the Moon and meteorites, which are rocks from space that have hit Earth, are of special interest to scientists. Invite students to look at the rock collection that they have created for their simulation. They should examine the "rocks from space" and select one rock. Go back to the class list of attributes for the attribute blocks. Ask students to select attributes in the lists that apply to their "space rock." Are other attributes important for describing their rock?

In their mission teams, students make a list of attributes that apply to their rocks.

CLOSING THE ACTIVITY

This part of the lesson should be closed by developing a data sheet for recording the information about "space rocks." Mission teams should report their ideas on attributes that might be important to record about the rocks. New attributes may be added to the earlier list developed from attribute blocks. For example, some students may want to add "has fossils" or "shiny-dull" as attributes, which are certainly important.

Each student should form the list of attributes into a data sheet for recording information about the rocks in part B.

In a later activity, students develop a measurement scheme for the hardness of rocks. It is a bonus if hardness is suggested as one of the attributes. However, if hardness is not included in the list, it can be saved as a new attribute for the targeted lesson.

Part B

GETTING STARTED

Give each student one "space rock." Organize the class into mission teams. Their task is to record both descriptive and measurable data about the "space rocks" in their mission team's collection. Every student should record data about all the rocks in her or his team's collection.

DEVELOPING THE ACTIVITY

In the process of doing this part of the lesson, the teacher may need to collect the whole class together to talk about how to measure certain attributes. Two attributes may be somewhat difficult for students. The estimation of both surface area and volume may need guidance from the teacher. Students may know formulas or even some measurement techniques for objects with regular shapes, such as attribute blocks, but these are ineffective for irregular objects. However, if certain mission teams have found good ways to estimate these measures, have them share their ideas with the whole class.

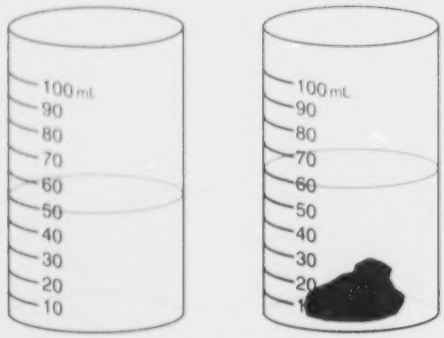
Surface area: Use an attribute block to review the notion of surface area and the units of measure associated with surface area. Try to help students think about surface area as covering the object with graph paper or aluminum foil with no overlaps. This technique can be used to approximate the surface area of irregular objects.

The discussion of surface area can include a series of approximations. Begin with a box that the rock just fits in as the first approximation. Hold up to the light the box with the rock in it. Students can see the gaps between the rock and the box. Remove one gap by carefully cutting off or "denting in" one of the corners with a gap. Continue this process to show a series of better and better approximations. This can serve as an introduction to the concept of limit.

Volume: The formulas do not work here. As one student said, "You can't do this; there isn't an *l*, *w*, or *h*." A new technique is needed. Use this opportunity to show one of the advantages of the metric system.

In the metric system, volume is measured in such units as cubic centimeters, or cm^3. Coincidentally, the amount of water that fills a 1-cm^3 container is 1 mL. So, if we place a rock into a graduated cylinder or beaker with a known amount of water, the amount of water in mL displaced by the rock is its volume in cm^3.

For example, use a 100-mL graduated cylinder filled with 50 mL of water. Put a small rock in the graduated cylinder. The water rises to the 60-mL mark. This means that the rock displaces 10 mL of water, which has a volume of 10 cm^3. The volume of the rock is 10 cm^3.



60 mL – 50 mL = 10 mL. The rock displaces 10mL of water, which has a volume of 10 cm^3.

CLOSING THE ACTIVITY

Students from each mission team report to the class about the attributes of their most interesting rock. Different students can talk about the different attributes and how they measured the rock for some of the attributes. From this activity, the list of attributes may be increased. Some students may have investigated an attribute not contained on the earlier class list. Thus, a need may arise to return to mission teams and record more data about rocks.

All students should write in their log books about the mathematics they used in this lesson.

NCTM Teaching Standards: ***The teacher of mathematics should promote classroom discourse in which students try to convince themselves and one another of the validity of conjectures and answers.***

(NCTM 1991, p. 45)

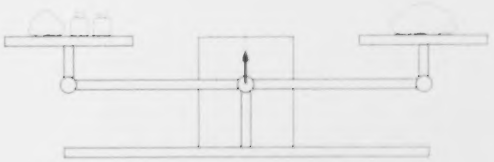
Part C

GETTING STARTED

Some notions of algebra can be developed by considering the mass of the space rocks. Give each team a pan balance and some standard masses to measure the mass of the space rocks. The standard masses can be commercially made centicubes that have a mass of 1 gram (1 g) or any other standard masses. Central to this activity is the preparation of the materials. The teacher must examine the rock collection for each team carefully. Teams should be given too few standard masses to determine the mass of each space rock. The point of this activity is to force students to use smaller rocks and standard masses to find the mass of larger rocks.

DEVELOPING THE ACTIVITY

Tell the teams that their task is to describe the mass of the largest space rock in their collection. They may use only the materials they have in the activity laboratory package. Students discover that they do not have enough standard masses to balance the rock. The typical first action of the students is to ask the teacher for more standard masses, which should not be given. At this point, encourage students to think of ways to balance the rock with materials in the laboratory package.



Students discover that a smaller rock can be used with standard masses to determine the mass of a space rock.

It is hoped that students in each team will see that a smaller rock can be used with standard masses from the provided set to determine the mass of the larger rocks. The students can combine a smaller rock with standard masses to balance a larger rock.

Have students write a sentence that describes the mass of a large rock by using a smaller rock and standard masses. For example, "The mass of the large reddish rock equals the mass of the small brown rock plus three units of mass," which can be translated into an algebraic sentence:

y = the mass of the large reddish rock,

x = the mass of the small brown rock,

and

$$y = x + 3$$

Other rocks will have different masses. Another rock may have a mass of $x + 7$. Students can compare these two rocks to see that $x + 7$ is greater than $x + 3$.

Challenge teams to express the mass of each of their rocks with standard masses or with other rocks and standard masses.

CLOSING THE ACTIVITY

Teams exchange rock collections and make new algebraic sentences to express the mass of space rocks. Once they have found writing algebraic sentences routine in this activity, ask them to write in their log books about their experience with using algebra.

In learning to express the mass of rocks algebraically, some groups may complete their work before others. Writing algebraic sentences is a challenge for some students and second nature to others. Developing the mission patch and designing the log-book cover for the module can provide additional learning experiences for students who complete assigned work early.

LESSON 2
HOW HARD ARE THE ROCKS?

Mission

To develop a scale of hardness for the space-rock collection

NCTM Mathematics Standards

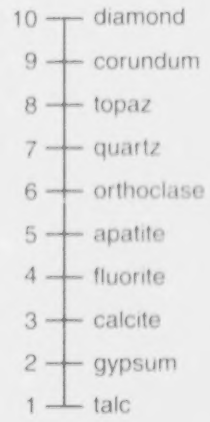
Measurement

Statistics

Materials: ***Log sheets; a collection of substances with ranging hardness: chalk, a penny, a dime, a wooden object, and so on; boxes; and a collection of rocks***

One task of scientists is to develop ways to describe what they encounter in the laboratory. Geologists in the space program, who are examining rocks from other celestial bodies, must describe specimens in terms that fit within the reference system of Earth geology. One of the attributes of minerals that are important to scientists is hardness. Hardness is described as the resistance that a smooth mineral surface offers to scratching. Some minerals, such as talc, are very soft. The diamond is very hard. In fact, a diamond can be scratched only by another diamond. Although an established scale of hardness does exist, this lesson requires students to use common objects from their environment to establish their own scale and then test the hardness of rocks in the class collection.

A scientist determines the hardness of a given rock by trying to scratch one of its smooth surfaces with another material of known hardness. In 1812, a geologist, Friedrich Mohs, proposed that relatively common materials be used as a scale of hardness. The scale is presented in order of increasing hardness: talc (1), gypsum (2), calcite (3), fluorite (4), apatite (5), orthoclase (6), quartz (7), topaz (8), corundum (9), and diamond (10). Each mineral can scratch those with lower numbers but cannot scratch those with higher numbers.



Mohs's scale of hardness

PURPOSE

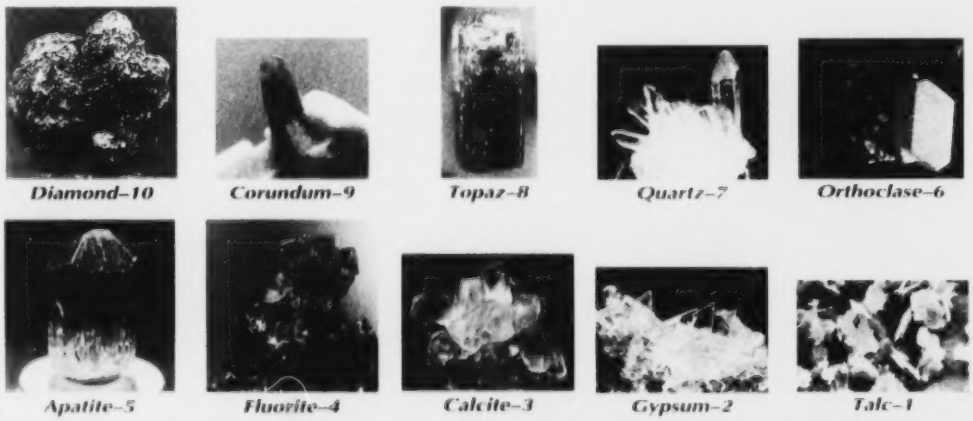
Students develop and use a descriptive and quantifiable scale of hardness for rocks. For most students, this is one of their first experiences in developing a valid scale for measuring some attribute of an object.

GETTING STARTED

Begin the discussion of hardness by defining the term. *Hardness* means the resistance to scratching by another object.

An example of the test of hardness that is used nearly every day in the classroom is trying to "scratch the chalkboard with chalk." As a result of trying to scratch the chalkboard, writing appears on the harder surface. The softer surface, chalk, rubs off on the harder one, chalkboard, and the softer one becomes smaller in size.

Ask the class to think of other instances in which they rub the surfaces of two objects together and one rubs off on the other. Create a class list of the ideas generated by the class. Some of these ideas may lead to students' including objects in their scale. For example, chalk is a good object for their scale.



Some minerals are relatively soft. The diamond is the hardest mineral on Earth.

Talc can be found at www.ceramics.com/polar.

All other minerals are copyrighted: © 1995, 1996 by Amethyst Galleries, Inc., mineral galleries.com.

DEVELOPING THE LESSON

Curriculum Connection: ***This is a good time to connect with the social studies curriculum and the topic of responsibility. Talk about students' responsibility to keep their neighborhoods and schools free of graffiti. Scratching a name or another saying on someone's property is disrespectful and unacceptable. Also, trees are harmed by carving. Students should be made aware of the general unacceptability of these types of activities.***

In the list, students are likely to include drawing with chalk on the sidewalk and say that chalk is softer than cement. Some students may have rubbed a penny on different surfaces, and they can tell about their experiences.

Through discussion, rank the objects that students mention in the descriptions of their experiences with the hardness of objects. Rank them as the scientists have done, from softest to hardest. The result might be a list like the following:

- Chalk
- Fingernail
- Penny

Confirm the ranking by demonstrating the scratch test. Does a fingernail scratch the penny? Will a fingernail scratch chalk? The teacher should demonstrate each test of hardness.

This street artist's drawing demonstrates that concrete is harder than chalk.

Once the ranking is confirmed, assign numbers to each object on the list. For example, in the foregoing list, chalk has a hardness of 1 and a penny has a hardness of 3.

Next, have students form their mission teams to examine the hardness of their "space rocks." They should use the same rocks they previously described in the "How Big Are the Rocks?" lesson. The data collected on hardness should be added to the data sheet for their rocks.

CLOSING THE LESSON

NCTM Assessment Standards: ***Students should be able to see the connection between instruction and assessment.***

(NCTM 1995, p. 22)

The teacher should place as many boxes in the front of the room as categories on the class hardness scale. The boxes should be labeled to indicate the levels of hardness. Ask a student from each mission team to place the rocks studied into the boxes according to their hardness. The distribution of the rocks should be discussed. The rocks in each box should be counted and the number recorded on the chalkboard.

Once the recording is complete, students can make a bar graph in their log books to show the distribution. Additionally, they should write about their experience of formulating a scale for measuring something.

Hardness is a favorite theme for mission patches. Students may include some message about graffiti within their patches. This connection among mathematics, science, and social studies is very meaningful to students.

EXTENDING THE LESSON

NCTM Teaching Standards: ***The teacher of mathematics should pose tasks that represent mathematics as an ongoing activity.***

(NCTM 1991, p. 25)

The distribution of rocks may not include many soft ones or hard ones. Challenge students to locate rocks or objects that can be tested for hardness and placed into the boxes for the softer and harder objects. This activity can be ongoing for several days or even weeks.

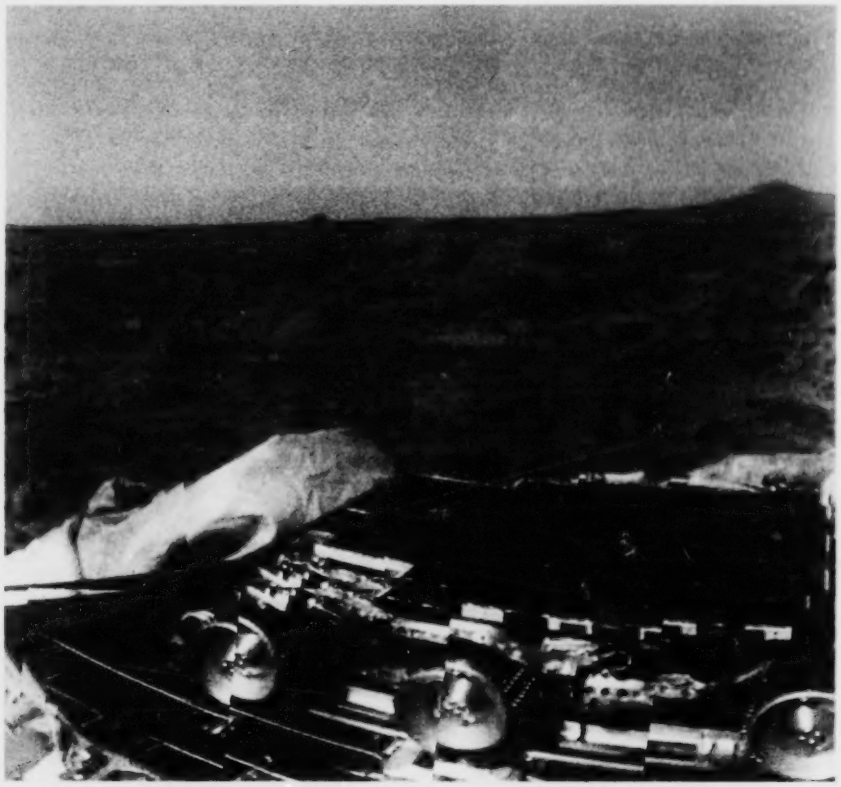
Some students will want to know if scientists really use this procedure to measure hardness. Have them do some research in the library, in the media center, or on the Internet to learn more about the scale for hardness. They should record the results of their research in the Space Rocks log sheet.

LESSON 3
WHERE ARE THE ROCKS?

Mission

To apply coordinate geometry to make and use a data map for a simulated geology expedition

When collecting data in the field, scientists try to keep track of where objects are found. The location may be an important clue to the nature or origin of a rock. Thus, these locations are cataloged so that the data scene can be re-created in the laboratory. This procedure will be very important as NASA scientists retrieve data from planet explorers, such as the Mars *Pathfinder*. The location of the rover designed to collect data about rocks and soil on Mars will be important. Scientists may want to send another rover or a robotic expedition to the same site to confirm the existence of an important geological find. Unless they know the exact location of the site, this return would be very difficult.



A photograph of Mars's landscape taken by Mars Pathfinder with Sojourner in the foreground

NCTM Mathematics Standards

Geometry

Number and Number Relationships

Link to Other Mission Mathematics Topics: ***Geologists and other field scientists are beginning to use GPS (Global Positioning System) units to record the location of discoveries in their work. Information on GPS can be found in the "Mission to Planet Earth" module in this book and in "Finding Our Way" in*** **Mission Mathematics: Grades 9–12.**

PURPOSE

Simulating actual tasks of scientists motivates students to participate in their mathematics classes. Using the mathematics that scientists use in the laboratory and in the field makes learning meaningful. In this lesson, students are involved in making a map of a field site by using the mathematics of coordinate geometry. Since all four quadrants of the Cartesian plane are used to develop the map, integers are important to the task. If students have not studied integers and the entire Cartesian plane, limit the activity to the first quadrant.

GETTING STARTED

Materials: ***Log sheets, yardsticks or metersticks, rulers, graph paper, rocks or colored counters, and prepared sand traps or outdoor "field sites"***

This activity can be done indoors or outdoors. Advance preparation is required for either location.

Indoors, the teacher must prepare sand-tray field sites for each mission team before class. The sand trays can be made from shallow cardboard boxes that have been lined with plastic to keep the sand in the box. In each box, six to eight counters in different colors are placed in the sand to simulate rocks. The locations for these "rocks" should be somewhat random, but a few should be in each quadrant of the box.

Outdoors, field sites must be lined off by the teacher before class. Yardsticks or metersticks can be used. Sites one yard or meter square are sufficient for the activity. As in the indoor activity, six to eight "rocks" are placed within the field site and distributed in all four quadrants. For the outdoor activity, rocks from the class collection can be used.

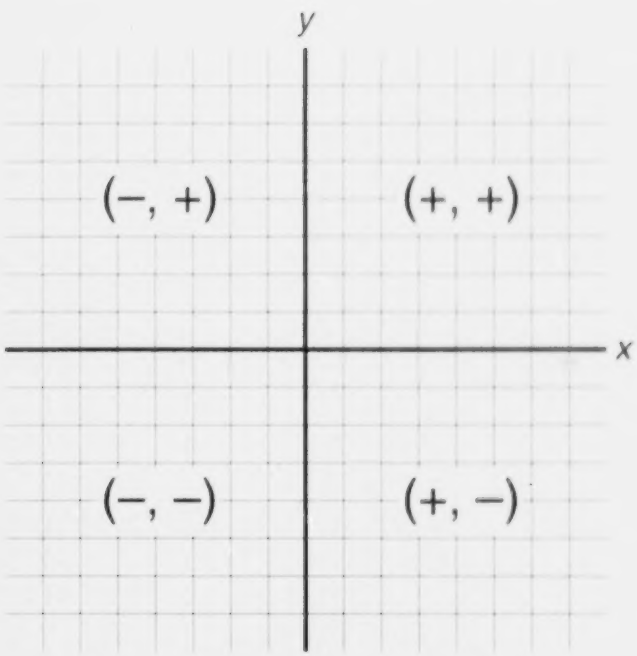
Assemble the mission teams and give them instructions before assigning their "field sites."

DEVELOPING THE LESSON

NCTM Assessment Standards: ***Assessment should be integrated with instruction and should be focused to ensure that significant mathematics is used by the students.***

Before the activity, tell students not to touch or move any of the rocks at their field site until given clearance. Invite them to look at the site carefully and discuss with their team members the descriptions of the rocks and their locations.

Give each team a piece of graph paper. Ask teams to create a scale for a "map" of the site to be shown on a coordinate grid. Since the sand trays or outdoor grids are larger than a piece of graph paper, students must use proportional reasoning to create their map. Note that for most middle school students, using a grid showing all four quadrants of the coordinate plane is appropriate. Some students will want to draw the axes in the sand. This is permissible, but after creating their map, they should rub out the axes for the next activity.



The four quadrants of a coordinate grid

Discuss the importance of accuracy in their efforts. Scientists who make these same types of maps understand that other scientists may want to re-create the site for further study. If the data are not accurate, the sites cannot be accurately re-created.

The data for this simulation should include a descriptive name for each rock or colored chip together with its location. This information should be formed into a data table. Students should also include as part of the data a scaled map of the location of the rocks.

A re-creation of the sites will be simulated in class. After each mission team creates a map of its site and a data table of ordered pairs, the rocks are removed from the site; only the data table is given to another team. The other team must re-create the site using only the data table. When the second mission team has completed its task, the field site should look like the map drawn by the original team.

While monitoring the development of the maps and the re-creation of the sites, the teacher can readily see which students can use proportional reasoning to make a map, record data involving integers, and use coordinates.

CLOSING THE LESSON

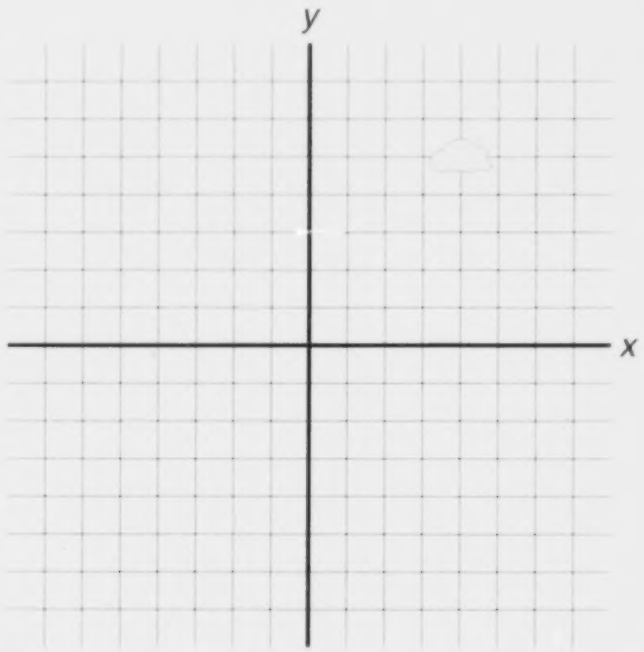
Each team shows its map to the class and justifies the placement of its rocks on the grid. The locations and justifications should be turned in as a written report as well.

On their log sheets, students complete the questions about the mathematics they used and learned in this activity. The teacher should be able to see a correlation among the classwork, the class presentations, and the students' comments on the log sheets.

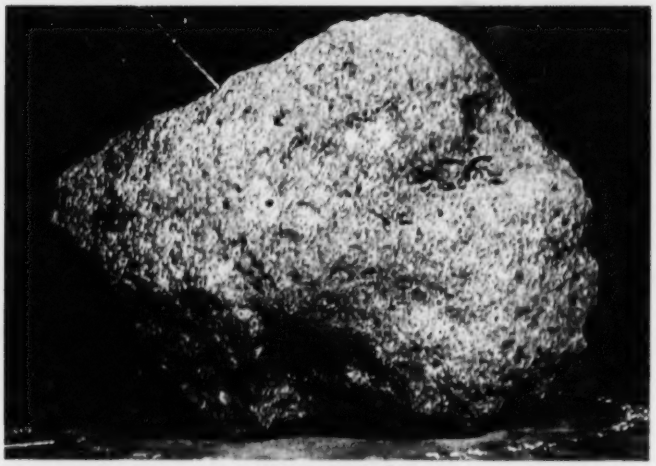
NCTM Assessment Standards:

Verification of students' knowledge should come from many sources.

A small coordinate grid and a picture of a field scientist are common elements of mission patches that students design during this unit. By including these images, students indicate what they saw as important in the module. As students decide what should be included in their designs, they have an opportunity to reflect on the mathematics learned.



The rock is located at position (4, 5) on this coordinate grid



A moon rock

SPACE ROCKS LOG SHEET

An astronaut on the Moon

Date: _____

Mission Specialist's Name: _____

Team Name: _____

Members: _____

_____

_____

_____

_____

_____

The things I did and the mathematics I used:

The things I found out and the mathematics I learned:

The things I wonder about and the mathematics I want to know about:

MISSION PATCHES

Mercury 9/Faith 7

Apollo 11

Gemini 11

Apollo/Soyuz

Mercury 4/Liberty Bell 7

Galaxy NGC 4639 as seen from the Hubble Space Telescope

HOW BIG IS OUR NEIGHBORHOOD?

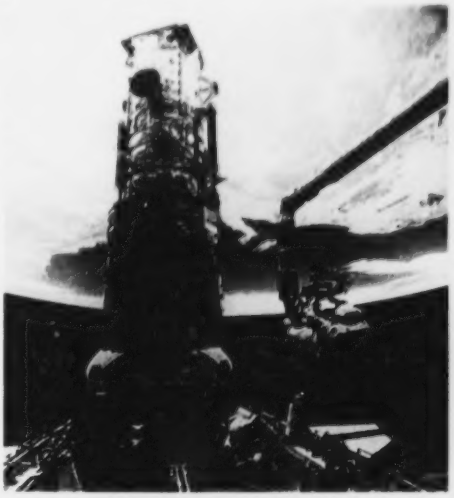
Being able to function successfully in our world involves becoming aware of our immediate neighborhood, understanding its location in the city, realizing that the local neighborhood interrelates with other neighborhoods and cities, and so on. If we think of our neighborhood as being our entire planet, our horizons are expanded to a point where we probably will not be able to experience other such neighborhoods in person. NASA is dedicated to studying "neighborhoods" in space. Among the questions that scientists seek to answer in the study of space science are these:

- What is the universe? How did it come into being? How does it work? What will be its ultimate fate?
- What was the origin of the Sun, our Earth, and the rest of the solar system? Do planets orbit other stars?

From years and years of studying the heavens with ground-based telescopes, we have gained a knowledge of the universe. We know that our star, the Sun, is one of perhaps a billion stars in our galaxy, the Milky Way. The Milky Way is one of a billion galaxies in the universe. These data make our space neighborhood seem very crowded. Billions of stars are an enormous number of stars.

Furthermore, we know that Proxima Centauri, the star nearest to the Sun, is a distance of only 4.3 light-years from the Sun. The nearest galaxy to the solar system, the Andromeda galaxy, is 2.5 billion light-years from Earth. Distant galaxies may be as far as 10 billion light-years away. Indeed, the universe is very large, and great distances separate stars and galaxies.

The ability of scientists to expand our knowledge about the universe has been hampered by Earth's atmosphere. The weather and the generally hazy atmosphere of Earth often distort and dim the images of ground-based telescopes. Scientists have counteracted this problem by placing telescopes in higher and higher places in the world. However, the Space Shuttle, with its ability to carry heavy loads, has made it possible to place a telescope in orbit high above Earth's atmosphere. The Hubble Space Telescope (HST) was placed in orbit by the Space Shuttle in 1990. The HST weighs 11 600 kilograms. It is 13 meters long and about 4 meters in diameter at its widest point. It is about the size of a railroad tank car.

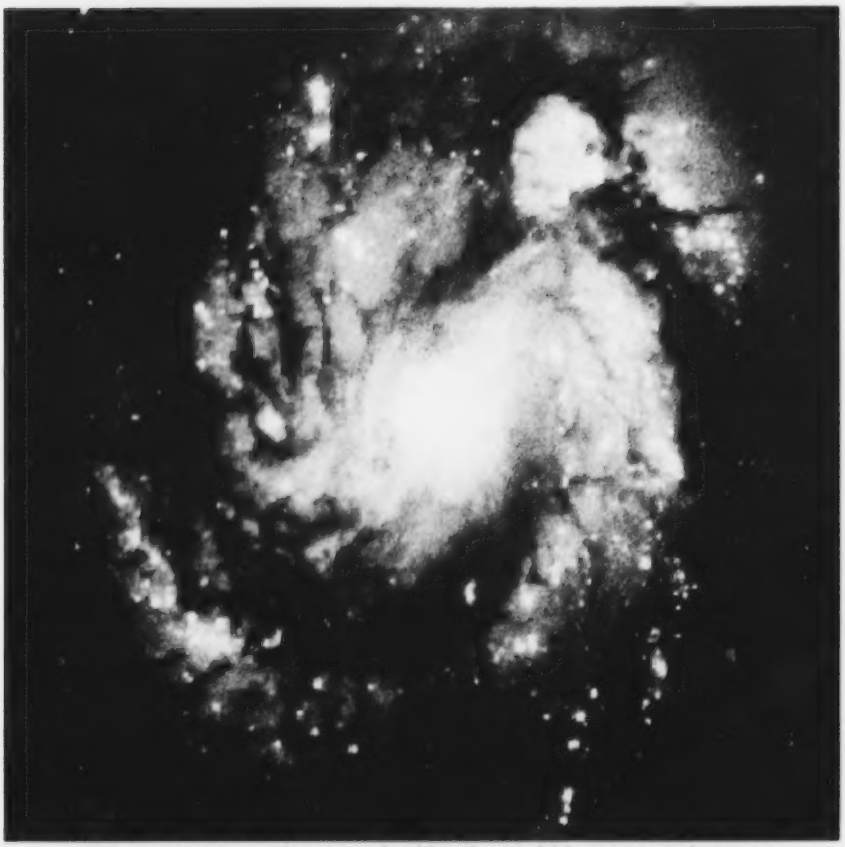


Astronauts working on the Hubble Space Telescope

The HST has allowed scientists to make many discoveries since it became operational. Scientists now have—

- the first conclusive evidence of the existence of black holes;
- indications that the universe may be much younger than previously thought;
- the first direct evidence that the universe is evolving;
- information that quasars do not dwell in cores of galaxies but are isolated in space;
- indications that dark matter in the universe is more exotic than once thought.

Through the continuing research efforts of NASA scientists and their collaborating colleagues as they use the high technology of the space program, we are learning much about the universe. Our knowledge of our neighborhood is growing exponentially.

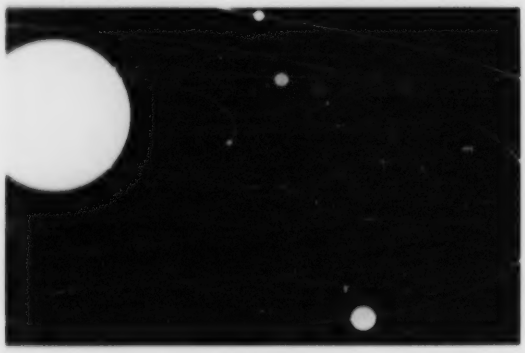


Galaxy M100, as photographed by the Hubble Space Telescope

MODULE
TAKE A SPIN

Module Mission

To apply common multiples, proportions, algebraic thinking, measurement, and fractions to gain a better understanding of the solar system



Most middle school students have some knowledge of the solar system. They know that Earth has a moon and revolves around the Sun. They probably can name several planets and are familiar with Mars and Saturn. Some students will have learned a mnemonic device for remembering the order of the planets from the Sun to Pluto, such as My Very Earnest Mother Just Sat Upon Nine Pins.

Probably only *Star Trek* fans or budding astronomers know that this order is not constant. At times, Uranus is the outermost planet, not Pluto. Because they are elliptical, the orbits of Pluto and Uranus are sometimes configured so that Pluto is actually closer to the Sun.

Students' understanding—in fact, even adults' understanding—of the solar system grows each time they have an opportunity to engage in meaningful learning activities related to space-science concepts. Although the study of space is a popular topic for elementary school science, middle school students can gain a great deal from considering the solar system again. They can use their increased mathematical power to improve their understanding of space science.

INTRODUCTION

The unit contains four distinct lessons. The activities in these lessons can involve between ten and fifteen class periods; the time depends on how many optional portions of the lessons, extensions, and assessment activities are used. Part of lesson 1 is used in lesson 2, and part of lesson 2 is used in lesson 3. Even with this connected design, the later activities can be taught separately if the teacher reads the earlier lessons and prepares some materials based on them.

- "Orbit Lab": In this introductory lesson, students explore some rudimentary properties of orbits. Through the use of manipulatives, students experience some of the properties of orbits and think about the mathematics associated with the properties.
- "A Planetary System": Students gather data about our solar system. They use library resources, including NASA publications, to create a class chart or poster containing information about the planets, their moons, and the Sun. Additionally, students begin exploring the characteristics of orbits, including that of an imaginary planetary system, Delphi. In this part of the lesson, students use concepts from their study of fractions and number theory to predict the occurrence of planetary alignment.
- "Our Solar System": Using the chart of data about our solar system, students create a model showing the distances of the planets from the Sun. Proportions

NCTM Mathematics Standards

Number and Number Relationships

Number Theory

Measurement

Algebra

Related Mission Mathematics Activities: Mission Mathematics: Grades 9–12 ***has two activities related to this unit. "Modeling Elliptical Orbits" has a direct link to the content of the science concepts of this unit, and some of the mathematics content could be appropriate for middle school students taking algebra. The activity called "Scaling the Heights" also has a strong connection to this unit. Just reading these units will give teachers more background about the solar system and the mathematics used to solve space-science problems.***

Mission Mathematics: Grades K–6 ***has two activities that may be appropriate for students who have little knowledge of the solar system. Both "Probing the Planets" and "Gravity and Weight" might be helpful to teachers in building students' knowledge of the solar system.***

NCTM Teaching Standards: ***Teachers should provide and structure the class time necessary to explore sound mathematics and grapple with significant ideas and problems.***

(NCTM 1991, p. 57)

Writing in Mathematics: ***Students begin to internalize their mathematics learning when they must formulate their thoughts and write about their learning. The consistent use of log books allows the student and the teacher to track the path of learning for students as they experience "Take a Spin."***

A view of Earth from the Moon

are used to scale the distances among the orbits. In this first attempt to build a model of the solar system, students use model planets that are not proportional with respect to size.

- "1000-Yard Solar System": With some experience trying to build a model of the solar system, students have begun to conceptualize its immense size. Students are now ready to create a model in which both the orbits and the sizes of the planets conform to the same scale. Proportional reasoning is used to establish the distances in the model as well as the sizes of the planets. The culmination of the lesson involves measuring and creating the model outdoors.

The outdoor activity in the "1000-Yard Solar System" lesson requires advance preparations and clearances from the school administration. Please read the suggestions in the lesson.

Mission log books remain significant in this module. Journal writing can be an important part of learning mathematics. By formulating their thoughts about their understanding of mathematics related to space science, students are completing an essential step in the learning cycle—reflection. A sample log sheet is included on page 38.

Developing a mission patch continues to be an important part of the module. Some students are more adept at reflecting on what they have learned if they can use art. Developing patches that show both the space-science mission and the related mathematics allows students to engage in important reflective thinking. The patches can be used as log-book-cover designs. Illustrating the cover of the log book can become an ongoing activity as each lesson of the module is closed.

LESSON 1
ORBIT LAB

Mission

To explore concepts related to orbits

To use measurement and statistics in a real-world application

NCTM Mathematics Standards

Statistics

Measurement

In this first lesson, students explore concepts related to orbits. Although students may have learned that planets are in orbit around the Sun, they may not have had an opportunity to think about some of the basic principles of orbital mechanics. Since this lesson involves the hands-on collection of data, it is important to group students into mission teams of three to five members. Reinforce the idea that although flying in the Space Shuttle is one type of mission, many research activities within space science can also be called missions.

Weather satellites, Space Shuttles, and the Moon are just some of the many objects that orbit Earth.

PURPOSE

The introductory discussion helps students develop the vocabulary and concepts that are used in the subsequent activities of this unit. The laboratory experiences assist the students in constructing their knowledge about orbital mechanics. Using a relatively constant speed for an orbiting planet, students explore the relationship between the size, or radius, of an orbit and its period.

Part A

GETTING STARTED

In this whole-class portion of the lesson, brainstorming is used both to encourage students' interest in the lesson and to allow the teacher to assess students' knowledge level. If brainstorming is a new class activity, the teacher needs to set guidelines for students' participation. Students should be encouraged to give their ideas freely and openly. It is important that all responses be accepted as valid conjectures. The rejection of a student's idea will only discourage another student from making a conjecture. These conjectures can be reviewed at a later time in this lesson or near the end of the unit to determine which ones seem most valid. These ideas can be noted in a class record for the unit on a bulletin board or chart.

NCTM Teaching Standards: ***The teacher of mathematics should orchestrate discourse by listening carefully to students' ideas and deciding what to pursue in depth from among the ideas that students bring up during the discussion.***

(NCTM 1991, p. 35)

DEVELOPING THE ACTIVITY

Ask an open-ended question, such as "What are some examples of objects that are in orbit around Earth?"

In a brainstorming session, ideas should be elicited from students; the teacher should not inject examples. Great patience may be required to get the first response. The "wait time" for subsequent responses should be reduced. List all student responses on chart paper or on the chalkboard. If the chalkboard is used, have a student record the list on paper for future use.

Do not be surprised if students voice misconceptions about astronomy. Many students have not yet constructed their understanding of the relationship among moons, planets, and stars. They may suggest that the Sun or planets are in orbit around Earth. At this point in the unit, these should be accepted as conjectures. As the lessons of the unit develop, the list of conjectures can be revisited and

NCTM Assessment Standards: ***When teachers have a good understanding of what their students know and can do, they are able to make appropriate instructional decisions.***

(NCTM 1995, p. 45)

CLOSING THE ACTIVITY

The brainstorming session should indicate to the teacher the students' understanding of orbits and basic astronomy. This information is valuable for helping the teacher decide on the amount of time needed to complete all parts of this activity.

Conclude with a presentation of the formal concept of an *orbit:* An object is considered to be in orbit if it is traveling in a circular or oval (elliptical) path around Earth or another object in space. The time it takes for an object to travel through one complete orbit, or revolution, is called the *period* of the orbit.

Part B

GETTING STARTED

Materials: ***Each mission team needs the following materials: Approximately six feet of string, six heavy washers, one rubber stopper, three inches of masking tape, a stopwatch, a meterstick, a calculator, and graph paper.***
Some of these materials should be available from the science teacher.

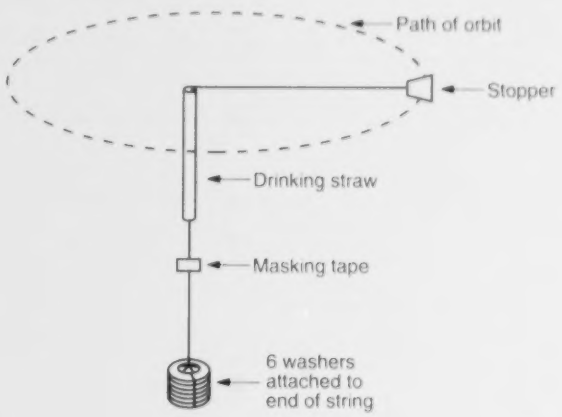
This laboratory activity is appropriate for small groups of students. Mission teams of three to five students should be formed. Roles for four students are presented below. These roles can be combined or shared for groups of three or five.

Roles	*Task*
Spinner	Spins the orbit simulator at a uniform speed
Timer	Uses the stopwatch to record time
Counter	Counts the number of revolutions
Recorder	Records data

DEVELOPING THE ACTIVITY

Each mission team needs to assemble the orbit simulator as shown below.

NCTM Teaching Standards: ***The teacher of mathematics should orchestrate discourse by deciding what to pursue in depth.***
(NCTM 1991, p. 35)



Safety Tip: ***Students should be warned against letting go of the spinning device. Caution students about fastening the cork securely to the string.***

Some students may not be familiar with the term *simulator.* Take time to discuss the notion of simulators as models of real-world settings. They are important for learning in laboratories, training in the workplace, and training in the military. The development of simulators has become an important and growing industry.

The distance from the bottom of the stopper to the straw is the radius of the orbit. For trial 1, the radius should be 60 centimeters. Masking tape is placed on the string about 2 centimeters below the straw. The mission team's spinner holds the straw above the level of his or her head, keeping the masking tape in view. The student spins the simulator by moving his or her wrist in a circular motion. The spinner continues to spin the stopper so the masking tape stays approximately 2 centimeters from the bottom of the straw.

Hold the straw loosely enough so the string can slide easily up or down. Note that increasing or decreasing the speed causes the tape to rise or fall. At a uniform speed, the tape and radius remain constant.

Once the mission team's spinner has mastered keeping the speed constant, the counter tells the timer to begin and counts thirty revolutions. The counter should count out loud so that the timer will be ready to stop at the end of thirty revolutions. The mission team's recorder enters the time into the data sheet. See data sheet 1 at the end of this unit.

Repeat the process for 65, 70, 80, and 85 centimeters. Each student on the mission team should record the results in the first chart on data sheet 1.

Each student plots the collected data on a graph, which should show radius on the horizontal axis and time on the vertical axis. Make certain that the axes are labeled. After the data are plotted, a discussion is necessary. At this point, the students should sketch a curve through the points. Middle school students may want to use a straight line. They may need to be encouraged to draw a curve if that is the pattern of their data. Reinforce that they are sketching the line.

If the students have not noticed, point out that some data are missing. There is no entry for a radius of 75 centimeters. Have students predict the value of the missing data by using the graph. This time should be recorded on the data sheet. The predictions of all mission teams should be shared.

Since students usually make different predictions for 75 centimeters, the whole class should discuss the accuracy of the predictions they have made. The notion that 100 percent accuracy is unlikely should be an outcome of the discussion. Predictions using approximations are subject to measurement error. The idea is to reduce the error as much as possible. One way to do this is for each mission team to collect and graph the data several times. If the data are consistent, then predictions become more acceptable.

Another way to improve predictions is to use the predictions of all the mission teams. Use a line plot of the individual predictions of all students to determine a class prediction. One technique for forming the line plot is to draw a number line on the chalkboard and affix sticky notes containing the individual predictions at appropriate places. If statistics has been included in the school mathematics curriculum, take this opportunity to introduce or practice stem-and-leaf plots or box plots as a means of looking at data to determine a class prediction.

Prediction is used in many research areas of aerospace science. For example, NASA scientists will need to predict the location and speed of the space station so the Space Shuttle or another orbiter can dock successfully. The key to successful docking will be to reduce the error to a very small one. Pilots of orbiters make corrections during flight to modify the predictions and complete the docking. The goal is to eliminate the need for such corrections by improving predictions.

In many real-world applications, a predicted value that is within 10 percent of the experimental data would be considered a good prediction. Considering the accuracy of the measurements in this experiment, 10 percent would be acceptable. To determine the percent of error, an actual time is needed.

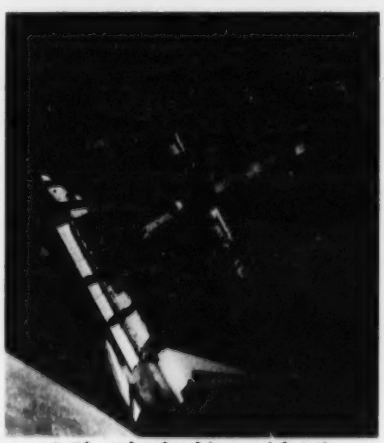
Calculation of accuracy:

$$\left| \frac{\text{predicted value} - \text{actual value}}{\text{actual value}} \right| \times 100 = \text{error (\%)}$$

The predicted value in the accuracy formula was determined as a class in the line-plot exercise. Thus, the predicted value is the agreed-on class prediction.

Next, have students return to their mission teams, collect data for 75 centimeters, and record the time. This experimental value will become the actual value

Teaching Tip: ***Students who are unfamiliar with stopwatches will find short durations of time difficult to measure. Thirty revolutions are recommended in the lesson to improve the accuracy of the measurements. The number of revolutions can be adjusted according to the students' ability to use the stopwatches.***



A Shuttle docking with Mir

Teaching Tip: ***Note that absolute value is used in the accuracy formula to avoid negative percents. This can be an ideal time to discuss the notion of absolute value in more detail.***

in the accuracy formula. Students may use calculators to determine the accuracy of their predictions.

Calculation of accuracy in this experiment:

$$\left| \frac{\text{class prediction} - \text{experimental value}}{\text{experimental value}} \right| \times 100 = \text{error (\%)}$$

CLOSING THE ACTIVITY

Mission teams can repeat their experiment to test the accuracy of new predictions. Have them use different lengths of string. Longer strings make the counting of revolutions easier.

CLOSING THE LESSON

All students should take time to write in their log books about what they learned in this lesson. The Solar System log sheet at the end of the unit has guiding questions to assist students in their reflections.

Some students may want to begin thinking about their mission patch for the "Take a Spin" unit.

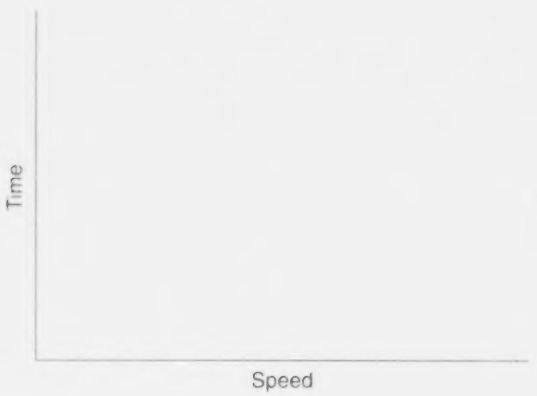
EXTENDING THE LESSON

Students can determine the period of the stopper orbits by dividing the time for thirty revolutions by 30. The radius versus the period can be graphed, and predictions can be made for the missing data.

Students can calculate the speed of the stopper using

circumference × number of revolutions/time.

Graphs can be made of speed versus time or speed versus period.



Graph of time versus speed

LESSON 2
A PLANETARY SYSTEM

Mission

To determine the time required for planets to become aligned in orbit

NCTM Mathematics Standards

Number Sense

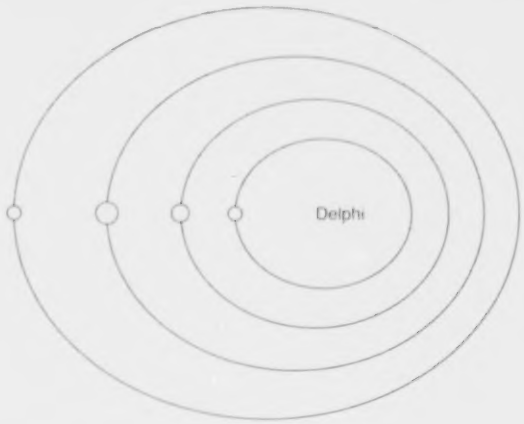
Number Theory

Patterns and Functions

Geometry

Problem Solving

Through the research of NASA's scientists, we are beginning to identify planets in other star systems. In this lesson, students study the planets of the solar system and think about the mathematics of an imaginary system of planets orbiting an imaginary star, Delphi. Students are challenged to solve a problem related to the alignment of planets in orbit around Delphi. This problem can be extended to the solar system.



PURPOSE

The purpose of this lesson is to give students experience with least common multiple, a mathematical concept that is important to calculating with fractions and has many applications to the real world. This application to space science helps students understand the importance of the least common multiple in a motivational context.

NCTM Assessment Standards: ***Student assessment should be aligned with, and integral to, instruction. Multiple sources of assessment information should be used. All aspects of mathematical knowledge and its connections should be assessed.***

Part A

GETTING STARTED

A whole-class discussion is used to make a list of the facts the class knows about our solar system. The teacher uses classroom discourse to determine the general knowledge of class members about our solar system and asks questions and poses tasks related to facts about the solar system.

- What is the relative size of the planets in the solar system?
- Order the planets according to the number of moons they have.
- Order the planets by size.
- Order the planets according to their distance from the Sun.

Assessment Tip: ***In this getting-started phase of the activity, the teacher is assessing the content knowledge of the student to make decisions about the next phases. The knowledge is used to develop the content and manage the class.***

The students should demonstrate their present understanding of solar-system astronomy, but the teacher must elicit data from them about their understanding of the large numbers involved in astronomy. Ask students about how they think about the size of these numbers. Determine how they comprehend the relative magnitudes of sizes and distances.

By listening and observing during the discussion, the teacher can make better decisions about grouping students for later activities in the lesson. For example, during the research part of the lesson, students with high levels of knowledge should not be paired with those with little knowledge. If new mission teams need to be formed for exploratory work, assigning a student with a higher degree of knowledge to each team would be beneficial.

DEVELOPING THE ACTIVITY

Begin by setting up research teams. Many techniques are available to form pairs of students for research. If students exhibit a uniform level of knowledge, a random pairing can be achieved by having students draw cards. Pairs of cards with the name or picture of a planet, a moon, the Sun, or an asteroid make up the deck of cards. Students who draw matching cards research the topic indicated. In a large class, some of the planets can be duplicated so that two or three pairs of students research the same topic.

Cards with names or pictures of the planets, moons, and the Sun

If the pairs are assigned by the teacher, the drawing will determine only the topic of the research.

Design a list of information that all research groups should complete about their topic. Students should brainstorm to make the list. All data that interest students are important. But be certain to guide the discussion so that the following topics are on the list:

- The size of the planet
- Facts about the orbit of the planet
- The mean distance from the Sun
- The number of moons

The information needed to complete the task can be found in various sources. NASA has resource materials on planets and the solar system that can be placed in the school library. (See the resources in the appendix of the book.) Science books and encyclopedias have many of the desired facts. If the opportunity is available, students can use the Internet to explore appropriate databases, including NASA's home page.

Each student creates a data chart for the material researched in the library or media center. A prepared data chart, The Planets at a Glance, is provided on page 46 as a resource for teachers.

CLOSING THE ACTIVITY

Technology Link: ***Every student should have access to a computer for individual and group work. If technology is available to students, use this opportunity to involve them with databases. Rather than make class charts of the data from the research effort, have students create a database of the discoveries.***

The activity culminates with the creation of a class chart or poster of all the data collected by students. The whole-group activity that results in the poster or chart is vital to the mathematics of this activity. It is important to have written or oral presentations (or both) of the research done by students. Two options are available:

- Ask students for data from their reports rather than take the class time for many oral reports. The reports can be done later as a getting-started activity for lesson 3, "Our Solar System."
- Use this time for student reports. From the reports, important data can be added to the class chart or poster.

As the class summary is developed, the teacher must focus the students' attention on the magnitude and relative magnitude of the measures associated with the planets. Through research and discussions, students should have improved their capability to understand and compare large numbers.

Attention should also be given to data about the orbits of the planets. Thinking about these orbits is important to the next activity in this lesson.

Part B

GETTING STARTED

Initiate the activity by asking the class what they know about the Hubble telescope and about what has been discovered through this orbiting telescope. Since new discoveries are occurring on a regular basis, refer to the NASA home page on the Internet to collect data. The address of the home page is www.nasa.gov. Present the following scenario to students:

> In this activity, we will study the imaginary star system called the Delphi system. This system has only four planets. By some chance, the first photograph of the Delphi system showed that all four planets were in alignment. Scientists began to wonder how often this alignment would occur. Your task is to explore this idea and try to predict when this event will occur again.

The Delphi system should be presented as a system where all planets orbit in the same plane. This example is *not* a true model of a planetary system, but it simplifies the situation for middle school students.

Materials: ***Five objects with one (the star) being larger, a piece of chart paper that can be used to draw four orbits around the star, and a compass***

Teaching Note: ***An important component of mathematical thinking is mathematical modeling. In the initial process of making mathematical models for real-world settings, mathematicians sometimes impose conditions on a situation that simplify the model. In this activity, some assumptions are made to allow middle school students to think about a relationship of orbital periods. It is assumed that orbiting bodies travel at constant speeds and that the orbits are coplanar.***

DEVELOPING THE ACTIVITY

The mission teams of three to five students formed in the "Orbit Lab" activity initiate their work by naming the four Delphi planets. With names picked, they are ready to begin studying the orbits of these four planets. Record these names in table 1 on data sheet 2.

Begin with a simulation of the movement of the planets in their respective orbits by using manipulatives. Have students experiment with orbital paths by moving the "planet" manipulative on paths drawn on chart paper. Have them speculate about which planet would take the least time to orbit the star. What about the longest time?

In this lesson, we are concerned only with the periods of the Delphi planets. A period is defined as the time for an orbiting body (planet) to complete one revolution around another body (star). This activity involves patterns among the given periods of the Delphi planets. Sample data sets follow to be used with data sheet 2 on page 40.

The Orbital Periods of Delphi Planets

Planets	*Data Set 1*	*Data Set 2*
A	2	1
B	3	2
C	4	3
D	5	4

Teaching Tip: ***Some students may know that the period of a planet is directly dependent on the length of the orbit and the speed of the planet. Discussion of this relationship may become an extension of the lesson.***

No unit of measure is associated with the orbital periods in the chart. Rather than use a year or some other familiar time unit, create a fictitious one called a *golly*. So according to data set 1, it takes 2 gollies for planet A to orbit Delphi. Planet B completes a revolution in 3 gollies, and so on. Record these values in table 1 on data sheet 2.

Many classes of middle school students need to simulate the planets' traveling in their respective orbits rather than deal with the problem abstractly. In these situations, a scaled value must be assigned to a golly. It may take a planet in the Delphi system many Earth days to complete an orbit, so it is better to simulate orbiting planets by using Earth seconds. Encourage the students to choose a number of seconds to be used in the simulation. They should record this scaled value under table 1 on data sheet 2.

Whether computing the least common multiple (LCM) for the various orbits or simulating the orbital periods to determine the LCM pattern, students will be aided by the tables on data sheet 2 on page 40.

Rather than have them attack the whole problem, encourage students to consider subproblems to solve the problem. Each student should predict the length of time needed for planets A and B to come back into alignment and record the prediction in table 2 on data sheet 2. They should then simulate the revolutions, record the results in table 3 on data sheet 2, and compare the results with their predictions.

One way to simulate the realignment of two planets is to use a student to represent Delphi and two more students to represent planets. The "planets" should be in alignment to begin. Ask "Planet A" to move in its orbit to the approximate position where it would be in 1 golly. If 5 seconds represents a golly, the student could walk slowly to the "1 golly position." The second student should be asked to move to the "1 golly position" in the same manner. This should be repeated for 2 gollies, 3 gollies, and so on, until the "planets" are realigned. The result should be recorded in table 3 on data sheet 2 and compared with the prediction in table 2.This process should be extended to planets A, B, and C, then to all four planets. Ask students to look for patterns in the data.

If the students see no connection to LCM after simulating the first data set, a second simulation exercise can be done with data set 2.

Sometimes another approach is more fruitful than repeating a simulation. Table 4 in data sheet 2 offers another way to think about alignment and LCM. The students should record a check in the column that represents a completed orbit for a planet. Table 4 is appropriate to use with data set 2.

CLOSING THE ACTIVITY

Discuss with students that when mathematicians work with newly discovered concepts or notation, they may see no apparent connection to the real world. It is often later that they discover the connections. The least common multiple is one instance of a mathematics concept with seemingly little connection to the real world.

But as can be seen, the LCM applies to orbital periods and simple notions of planetary alignment. It has other applications as well. Hot dog buns are packaged with eight buns in a package; hot dogs come ten to a pack. To make the number of buns and hot dogs come out even, use the LCM. Have students write in their log book about their understanding of the LCM and how it applies to space science. Also, since the LCM has many real-life applications, have students write about other ways in which they think the LCM applies to the real world.

EXTENDING THE LESSON

The lesson focuses on an imaginary star and its planets. Encourage students to think about our solar system and the alignment of planets. Review the solar system information on data sheet 3 on page 41, and have students assume that the planets of our solar system are in alignment. Ask them to determine how many years will pass before the planets are again in alignment. Students used subproblems to analyze the imaginary system of Delphi. They can employ that technique to begin aligning the planets of the solar system. It will be helpful for students to use technology to complete as much of the chart as they can.

LESSON 3
OUR SOLAR SYSTEM

Mission

To create a classroom model of the solar system

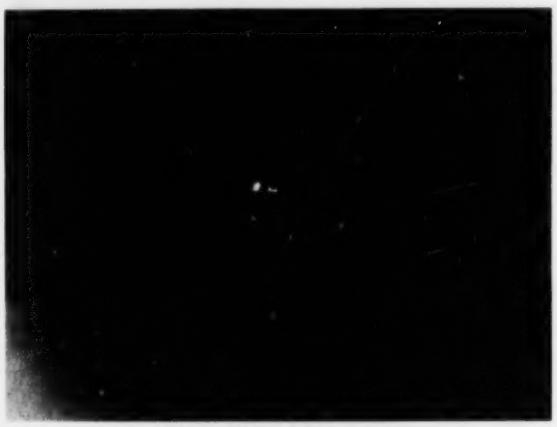
NCTM Mathematics Standards

Number and Number Relationships

Measurement

Algebra

The space science efforts of NASA have allowed us to improve our understanding of our neighboring planets. Since the 1960s, NASA scientists have been investigating Mars. Mariner 4, 6, and 7 were flyby missions that returned photographs and weather data from Mars. *Mariner 9* revealed large mountains and deep valleys on the surface of Mars. The two Viking spacecraft that were sent to Mars in the 1970s gave us a better understanding of the Martian surface. The latest generation of Martian explorers, *Mars Pathfinder* and *Mars Global Surveyor*, will refine our knowledge even further. We are learning more and more about this relatively close neighbor in the solar system, and gathering data about Mars and the other planets of the solar system is a complex task. To understand the planets, students need to develop an intuitive notion about the vastness of the solar system.



Mars Global Surveyor

PURPOSE

This lesson is a first step in the development of students' understanding of the large numbers associated with distances in space. Students use ratio and proportion to help them develop their number sense related to large numbers. Calculators help them build this understanding.

Part A

GETTING STARTED

In lesson 2 of this unit, "A Planetary System," a class chart or poster of the solar system was developed by using the results of students' library research. Use this chart to begin this lesson. If this lesson is selected as an independent lesson, a chart summarizing data about our solar system needs to be obtained or developed by the teacher. The transition from lesson 2 to this lesson can involve students' presenting their research reports as a means of reporting the poster data.

Using the class chart or poster, the teacher should conduct a discussion of the data about planets in the solar system. The immense distances and sizes make it difficult for middle school students to conceptualize the magnitude of the Sun, the planets, and the distances among them. This discussion should relate the sizes and distances to the students' level of number sense for large numbers.

DEVELOPING THE ACTIVITY

One way to increase students' understanding is to build scale models of the solar system. This activity presents the first opportunity to use this strategy. Although only estimations of ratios are employed in this activity, students begin to think about the magnitude of the solar system.

Challenge students to think about the relative sizes of the planets. Show them a set of Styrofoam balls or circular cardboard cutouts that could model the planets. Stress that these objects, the "planets," are not exactly to scale; they represent only four categories of the sizes of planets.

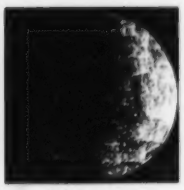
Show students an object of one size. Ask, "Which planets could be represented by a circle (or ball) of this size?" Do this for each size. The resulting categories

NCTM Teaching Standards: ***The teacher of mathematics should orchestrate discourse by deciding when to provide information, when to clarify an issue, when to model, when to lead, and when to let a student struggle with a difficulty and by monitoring students' participation in discussions and deciding when and how to encourage each student to participate.***

(NCTM 1991, p. 35)

Materials: ***String and Styrofoam balls or circular cardboard cutouts to represent planets: At least two circles about 30 cm in diameter, at least two circles about 15 cm in diameter, at least two circles about 10 cm in diameter, and at least three circles about 8 cm in diameter***

Mars



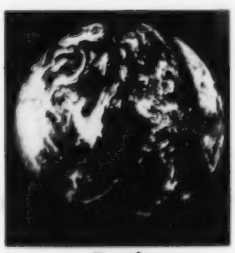
Mercury

Pluto

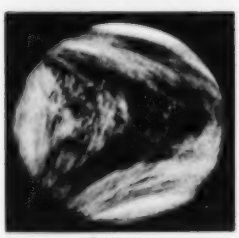
should have two very large planets (Saturn and Jupiter), two large planets (Uranus and Neptune), two medium planets (Earth and Venus), and three small planets (Mars, Mercury, and Pluto). Label a ball or circle for each planet, and give each "planet" to a student to hold.

After all the "planets" have been distributed, have the students with the "planets" stand in front of the class. Ask them to order the planets by size from smallest to largest and to name the planets. Then ask them to arrange themselves in the order of the planets from the Sun as they appear in the solar system.

Begin a discussion of the size of the solar system. Have each student with a planet select another student to hold it. Tell this new set of students that the Sun is in a corner of the room. Ask, "Where do you think Earth is located?" Have the class direct the student holding "Earth" where to stand in the classroom. Continue by having the class place the other "planets" in correct order where they think the planets would be in the solar system. The students are now in the correct order, but the distances from the Sun are most likely way out of proportion. In many classes, students do this activity without thinking about the data on the class chart. If this situation occurs, refer to the class data chart and discuss the relative distances between the planets. Repeat placing the planets, with more attention to the spacing.

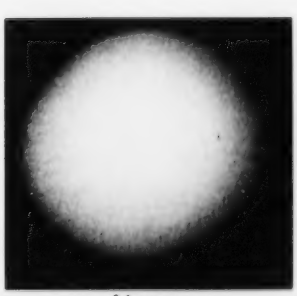


Earth



Venus

Saturn



Uranus

Neptune

Jupiter

CLOSING THE ACTIVITY

Have the class make a hanging display with the Styrofoam balls or cardboard cutouts to represent the order of the planets in the solar system. If enough materials are available, groups of students can make displays.

Ask students to think about the distances in the solar system and write their understanding in their log book. They can be encouraged to interview parents, siblings, or other adults about the size of the solar system and record their ideas.

Part B

GETTING STARTED

In part A of this lesson, the relative distances of the planets from the Sun were used to develop students' understanding of the solar system. In this part of the lesson, students begin to use ratio to develop a reasonably accurate scale representation of the distances of the planets from the Sun.

To present the pertinent data for this activity, see data sheet 4 at the end of the module and have students complete this data sheet.

Begin with a discussion of scale drawings and scale models. Ask students to give examples of where they have seen scale drawings or scale models. Students may mention that a map has a scale. Ask, "What does it mean to have a scale?" Ask students questions about developing a scale drawing of an automobile or another familiar object on a letter-sized piece of paper. Ask such questions as "If the automobile is 15 feet long, can we use a scale of 1 inch equals 1 foot?" Once they show an understanding of using ratio to create a scale, return to the problem of creating a scale model of the solar system.

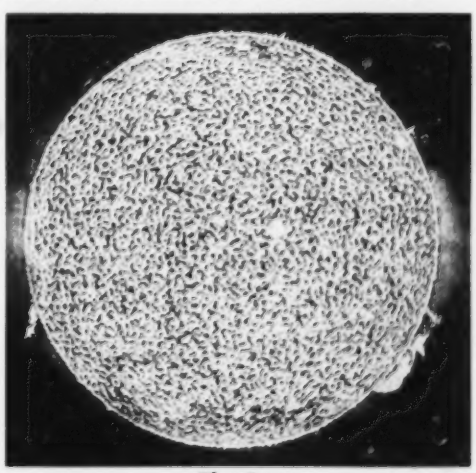
DEVELOPING THE ACTIVITY

Tell students that you want them to develop a scale model of the solar system for the classroom. This model should meet these criteria:

- All planets must fit inside the classroom.
- The planets must be far enough apart that the circles representing them do not overlap.
- All planets should be easily visible in the classroom.

In a typical classroom, these requirements cannot easily be met. However, the process of trying to develop the classroom scale shows students that the first attempt at solving a problem does not always lead to the best solution.

Begin the activity by assigning each student a planet other than Pluto. Tell students that the Sun is in one corner of the room and Pluto is at the opposite end of the room farthest from the Sun. Measure this classroom distance, and have students use it to develop the scale for the model with the help of their calculators. Use the mean distance from the Sun to Pluto on data sheet 4 and the classroom distance to set up the ratio for the scale.



The Sun

NCTM Teaching Standards: ***The teacher of mathematics should promote classroom discourse in which students—***

- ***use a variety of tools to reason, make connections, solve problems, and communicate; and***
- ***try to convince themselves and one another of the validity of particular representations, solutions, conjectures, and answers.***

(NCTM 1991, p. 45)

NCTM Teaching Standards: ***The teacher of mathematics should pose tasks that call for problem formulation, problem solving, and mathematical reasoning.***

(NCTM 1991, p. 25)

Materials: ***Calculators and Styrofoam balls or circular cardboard cutouts to represent the planets***

NCTM Mathematics Standards: ***Students should be able to select and use tools appropriate to solve a problem.***

(NCTM 1989, p. 8)

Suppose that the classroom distance between the Sun and Pluto is 40 feet. Use this value to set up a ratio with the actual mean distance:

Determine the classroom distance for Pluto:

The actual mean distance from Pluto to the Sun is 3 672 000 000 miles.

The classroom mean distance from "Pluto" to the "Sun" is 40 feet.

1. Convert miles to feet:

$$3\,672\,000\,000 \text{ miles} \times 5\,280 \text{ feet/mile} = 19\,388\,160\,000\,000 \text{ feet}$$

2. We have a ratio of

$$\frac{40 \text{ feet}}{19\,388\,160\,000\,000 \text{ feet}}.$$

That is, 40 feet in the classroom model represents 19 388 160 000 000 feet in real life.

Determine the classroom distance for Earth:

The actual mean distance from Earth to the Sun is 93 000 000 miles.

The classroom mean distance from the Sun is unknown.

1. 93 000 000 miles × 5 280 feet/mile = 491 040 000 000 feet.

2. So we have a ratio of

$$\frac{x}{491\,040\,000\,000},$$

where x = the classroom model of the mean distance from the Sun in feet, and

$$\frac{40}{19\,388\,160\,000\,000} = \frac{x}{491\,040\,000\,000}$$

$$19\,388\,160\,000\,000x = 40 \times 491\,040\,000\,000$$

$$19\,388\,160\,000\,000x = 19\,641\,600\,000\,000$$

$$x = 1.013071895,$$

or x equals approximately 1.013 feet.

Thus, the scale-model distance of Earth from the Sun is about 1 foot.

Teaching Tip: ***This activity involves computation with long distances. Since most calculators have eight-digit displays, students will need to use number sense to determine the proper place value for the distances. If scientific notation has been part of the curriculum, this is an appropriate time to practice the use of this notation.***

Have each student use a calculator and the scale to determine the classroom distance of his or her planet from the Sun. Select a planet and have all students assigned to this planet give their calculations of the distance. This is an opportunity to check students' use of the calculator to work out these scaled numbers. Select students to make the agreed-on scaled measurement and place the planet in the proper location. Continue until all planets have been placed in the classroom model.

When the model is complete, have the class evaluate the classroom model using the criteria set up earlier in the lesson. If the classroom is like most, the planets close to the Sun will be small distances apart. The circles representing some of these smaller planets may even overlap, which clearly violates one of the criteria.

NCTM Assessment Standards: ***Assessment should be integral to instruction.***

The teacher has a situation that allows more discussion about these distances. Have students comment on how close some planets are in the model. Ask, "Is this overlap caused by errors in measuring or calculating the scaled distances?" The actual planets do not overlap. The choice of the scale has made a model in which the planets near the Sun seem extremely close together. However, this situation is not realistic. The effort to contain the model within the classroom has made a model that is not the most desirable.

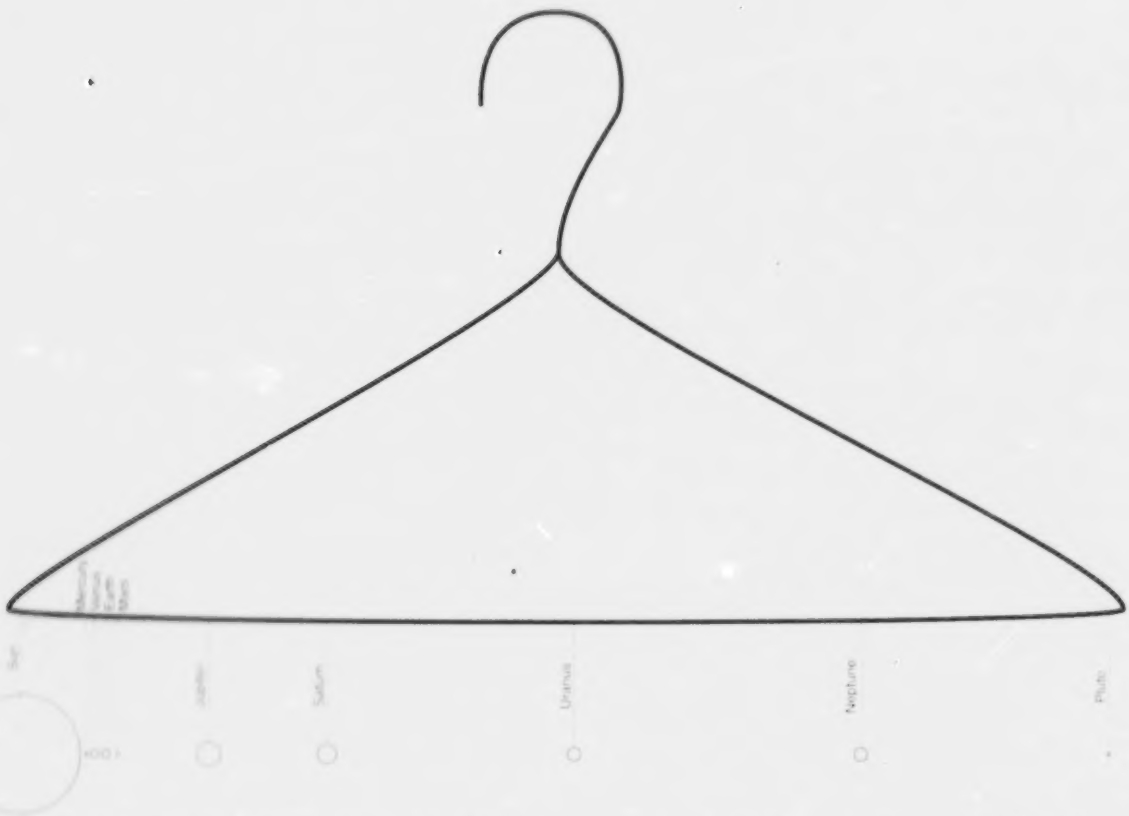
If the school building has hallways, students can repeat the development of the model by placing the Sun and Pluto at the opposite ends of the hallway. Some teachers have used a corner of the classroom for the Sun and allowed the model to extend out the classroom door. Placing Pluto outside the classroom can stimulate students in other classes to begin thinking about space science.

CLOSING THE ACTIVITY

Understanding the scale of space does not occur after one activity. It is a journey toward understanding. After this classroom activity, ask students to reflect on how their understanding of space has been altered. Have them write their thoughts in their log books.

Have the students write about the mathematics they have used and the role the calculator played in helping them solve the problems.

If some students finish their reflection activites quickly, they can begin thinking about their mission patches for "Take a Spin."



It is not practical to make a true scale model of the solar system in a limited area. In this model, the scale used for the distances from the Sun is different from that used for the sizes of the planets.

LESSON 4
1000-YARD SOLAR SYSTEM

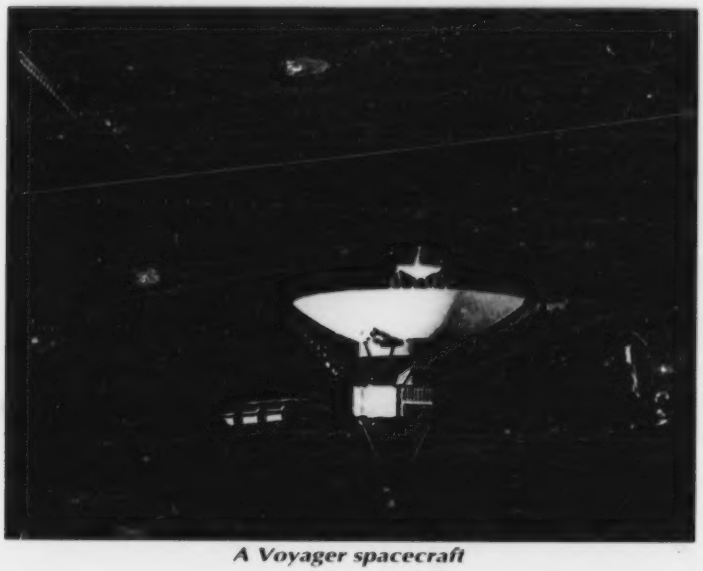
NCTM Mathematics Standards

- *Number and Number Relationships*
- *Measurement*
- *Algebra*

Mission

To create a model of the solar system in which both the sizes and the orbits of the planets are proportional to the same scale

Although much of the exploration of the solar system has focused on the planets closer to Earth, successful journeys have reached the outer planets. A series of Mariner and Pioneer spacecraft began humankind's initial reconnaissance of the solar system in the 1960s and 1970s. One spacecraft, *Pioneer 11*, became the first object from planet Earth to leave the solar system. Twin Voyager spacecraft mapped the four largest planets in the solar system. Their mission began with Jupiter in 1979. It concluded ten years later with Neptune. This time interval indicates the large distances that spacecraft must travel to explore our solar system.



A Voyager spacecraft

PURPOSE

After their experiences developing a classroom model of the solar system, students focus on the outer planets. They have begun to realize that for a model of the distances to look reasonable, the outer planets must be far from the Sun. As an added dimension, this lesson considers the size of the planets in the same model. Students use proportional reasoning to calculate both scaled distances between planets and scaled sizes of planets.

This lesson culminates with an outdoor activity that requires careful planning to ensure the safety of students, the adequate supervision of students, and a proper place to conduct the activity.

GETTING STARTED

A Viking spacecraft approaching Mars

In lesson 3, "Our Solar System," students built a model of the solar system with scaled distances between planets, but they did not draw the planets to scale. In most depictions of the solar system, either the planets are not drawn to scale, the distances between planets are not drawn to scale, or both. In this activity, students attempt to create a solar system that is accurately scaled in both respects.

To initiate a discussion about the immensity of space, use from earlier lessons the classroom model of the solar system and the class chart of data about the planets. Students gathered information about the sizes of planets as well as their orbits. Ask them to look at the size of Pluto in their model. "If we use the same scale for the size that we used for the distance from the Sun, how large would a model of Pluto need to be?" Metric data are presented in data sheet 5, on page 43. Customary measures are given in the margin on page 46.

In our classroom model, 40 feet represents 3672 million miles, the mean distance of Pluto from the Sun. If we round 3672 million miles to 4 000 million miles, then 40 feet represents 4 000 000 000 miles, or 1 foot represents 100 000 000 miles. One inch represents about 8 333 000 miles. Since the diameter of Pluto is not quite 1 500 miles, it needs to be represented by about 0.001 inch. Our model of Pluto will be very small—so small, in fact, that it is not practical to use in a model.

DEVELOPING THE LESSON

The problem is apparent from the "Getting Started" section of this lesson. It is very difficult to get a model that shows both the distances between planets and the sizes of planets on the same scale. Let's think about a new scale for depicting the orbits of the planets. "How long is a football field?" "Is our playground big enough to hold a football field?" This is a time to confirm conjectures. Going outside to measure 100 yards helps students as they think about longer distances.

Invite students to "pair share": "Discuss with a person near you the distances in our school neighborhood that are 200 yards long, 500 yards long, and 1 000 yards long."

After the pair sharing, have students report their ideas to the class. Make a list of school-neighborhood distances that correspond to the distances being considered. At the conclusion of the sharing, tell students that the class is going to make a model of the solar system that is based on 1 000 yards. The scaled distance from the Sun to Pluto will be 1 000 yards.

Show students how to set up a proportion to determine the distances for other planets. A chart of mean distances allows us to set up a ratio of the partial actual mean distance (Earth to the Sun) to the total actual mean distance (Pluto to the Sun).

Using miles, we can express the ratio as

$$\frac{93\,000\,000 \text{ miles}}{3\,672\,000\,000 \text{ miles}}$$

Using kilometers or astronomical units should give the same ratio. An *astronomical unit*, or AU, is the mean distance from Earth to the Sun. The distance from Earth to the Sun is 1 AU.

That is,

$$\frac{93\,000\,000 \text{ miles}}{3\,672\,000\,000 \text{ miles}} = \frac{149\,600\,000 \text{ kilometers}}{5\,913\,000\,000 \text{ kilometers}} = \frac{1 \text{ AU}}{39.44 \text{ AU}},$$

and all these ratios are about 0.0253.

Some reference charts use slightly different values for these large distances; therefore, some differences might appear in the ratios. However, the ratios should be very close.

We want to express the same ratio for the scaled distances in the model. We know that the total distance is 1 000 yards. The partial distance for Earth (x) must be calculated and is shown as

$$\frac{x \text{ yards}}{1\,000 \text{ yards}}.$$

Using astronomical units, we can set up the two ratios as an equation:

$$\frac{x \text{ yards}}{1\,000 \text{ yards}} = 0.0253$$

$$x = 1\,000 \text{ yards} \times 0.0253$$

$$x = 25.3 \text{ yards}$$

NCTM Teaching Standards: ***The teacher should convey the notion that mathematics is a subject to be explored and created both individually and in collaboration with others.***
(NCTM 1991, p. 115)

Mean Distances from the Sun

Mercury	***0.39 AU, or 36 million miles***
Venus	***0.72 AU, or 67.2 million miles***
Earth	***1.00 AU, or 93 million miles***
Mars	***1.52 AU, or 141.5 million miles***
Jupiter	***5.20 AU, or 483.3 million miles***
Saturn	***9.54 AU, or 886.2 million miles***
Uranus	***19.21 AU, or 1 782.9 million miles***
Neptune	***30.06 AU, or 2 792.6 million miles***
Pluto	***39.44 AU, or 3 672 million miles***

BEST COPY AVAILABLE

Teaching Tip: ***On a fraction calculator, once the ratio of the actual distances is set up, the student can use the fraction-to-decimal conversion key. The result is the decimal equivalent of the given fraction, but the display may show more than three decimal places. If so, round the answer to the thousandths place. This rounded number represents the scaled distance of Earth from the Sun.***

Diameters of the Planets

Mercury	***3031 miles***
Venus	***7514 miles***
Earth	***7921 miles***
Mars	***4215 miles***
Jupiter	***88 927 miles***
Saturn	***74 520 miles***
Uranus	***32 168 miles***
Neptune	***30 757 miles***
Pluto	***~1447 miles***

Magellan was deployed from a Space Shuttle during STS-30 in May 1989.

It is appropriate for students to use technology to solve these equations, since large numbers are involved. However, using technology involves making choices. Standard four-function calculators are sufficient, but fraction calculators or scientific calculators can be used.

Let students calculate the distances for each planet. The students' results should be entered into their log books, shared with the whole class, and recorded on a classroom chart.

Next, similar procedures can be used to determine the scaled sizes for the planets. We know that the mean distance from Pluto to the Sun is 3 672 000 000 miles. This value can be converted to yards:

$$3\,672\,000\,000 \text{ miles} \times 1\,760 \text{ yards/mile} = 6\,462\,720\,000\,000 \text{ yards}$$

The scale is

$$\frac{1\,000 \text{ yards}}{6\,462\,720\,000\,000 \text{ yards}},$$

or 0.000 000 000 1547.

We want the diameters of the model planets to be in the same scale as the model distances, and we know that the diameter of Earth is 7 921 miles.

Let x = the diameter of our Earth model in yards.

$$\frac{x}{7\,921 \text{ miles}} = \frac{x}{13\,940\,960 \text{ yards}}$$

$$\frac{x}{13\,940\,960 \text{ yards}} = \frac{1\,000}{6\,462\,720\,000}$$

$$x = 0.000\,000\,000\,1547 \times 13\,940\,960 \text{ yards}$$

$$x = 0.00\,21 \text{ yards}$$

Multiplying x by 36 converts the diameter to 0.078 inch, which can be rounded to 0.1 inch. Earth, therefore, would be represented by a sphere approximately 0.1 inch in diameter.

At this time, students should use their calculators and the information in the class data chart to determine the scaled size of each remaining planet. These values should be recorded in their log books, shared with the class, and entered on the class chart. The illustration on page 44 might help students understand the relative sizes of the Sun and planets. Some time should be spent discussing some real-world objects that are about the scaled sizes of the planets. For the teacher's reference, one sample result of students' work is shown on page 45.

Students are ready for an important phase of the lesson. We have calculated scaled values, and it is time to think about these values as they apply to the school neighborhood. If the object representing the Sun were placed at the front of the school, where would the object for Earth be placed? Have students discuss the scaled distances with reference to the school's neighborhood and make estimates for where the objects for the planets would be placed.

In the culminating phase of this lesson, have students mount their "planet" on poster board and clearly label it. Begin with the whole class at the Sun. Have one student hold the Sun while the rest of the class measures or paces off the scaled mean distances to the planets. To make the placement of the planets go more quickly, it is helpful to use the human pace as an approximation of a yard. Let students measure the length of the stride of several students to select one person whose stride is closest to 1 yard. Have this person pace off the distance

to Mercury. Leave a student holding Mercury, and have the students proceed to place the remaining planets. The students thus gain an understanding of the relative mean distances of the planets from the Sun and improve their intuitive notion of distances. The paced-off distances between proximate planets, as well as the scaled distances of the planets from the Sun, can be recorded by filling in a chart similar to the one on page 45, which presents sample student data.

CLOSING THE LESSON

It is time to close the lesson and debrief the students.

To close the lesson, ask students to write in their log books about their understanding of the size of our solar system. Ask them to comment on the mathematics they have learned while studying this lesson.

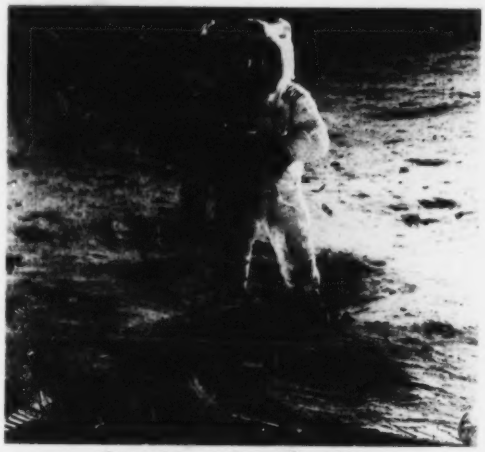
For the unit debriefing, have students do three things:

- Ask them to complete their mission patch for this unit. They should try to incorporate important science ideas and mathematics concepts in the design of the patch.
- The mission of this lesson was to develop a model of the solar system. Ask students to write about the important features of a good model of the solar system and the mathematics that helped them make the model.
- The Planets at a Glance reference sheet on page 46 can be given to students as a permanent record of some of their discoveries.

Mars Pathfinder *patch*

Mars Global Surveyor *patch*

SOLAR SYSTEM LOG SHEET



An astronaut on the Moon

Date: _____

Mission Specialist's Name: _____

Team Name: _____

Members: _____

_____

_____

_____

_____

The things I did and the mathematics I used:

The things I found out and the mathematics I learned:

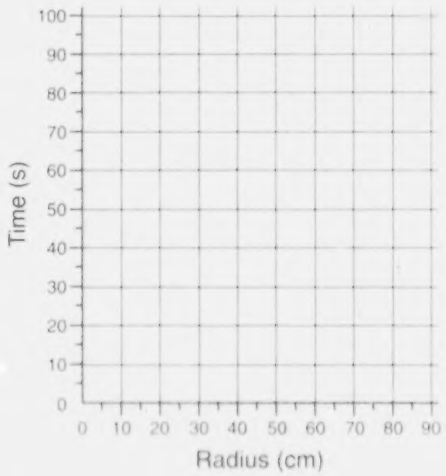
The things I wonder about and the mathematics I want to know about:

DATA SHEET 1
ORBIT SIMULATOR

1. Complete the chart showing the relationship between radius and time for thirty revolutions.

Radius (cm)	Time for Thirty Revolutions (s)
85	
80	
70	
65	
60	

2. Plot your data points on graph paper. Label the axes as shown below. Draw a smooth curve through the points. **Warning: unless the points are clearly in a straight line, do not draw a *straight line* through them.**



The relationship between radius and time for thirty revolutions

3. Use your data to make the following predictions:

- If the radius is 75 cm, use your graph to predict the time for thirty revolutions.

  Mark this point on your graph with an x and record your estimate for the time for thirty revolutions:

  _____ seconds

- How close to the actual time should you be for the prediction to be good?

  _____

  Explain your answer.

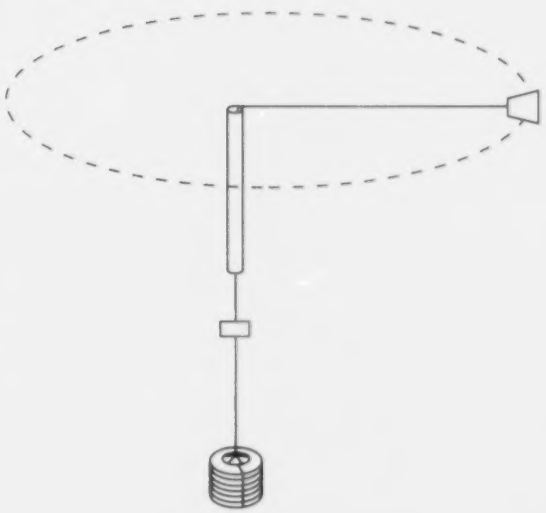
  _____

  _____

  _____

4. Select either the mean, median, or mode to report the "average" predicted time for your class. Record that "average" here:

   Circle one: mean, median, mode = _____



DATA SHEET 2
PLANETARY REVOLUTION AND ALIGNMENT IN THE DELPHI SYSTEM

The Orbital Periods of Delphi Planets

Planets	*Data Set 1*	*Data Set 2*
A	2	1
B	3	2
C	4	3
D	5	4

Table 1

Planet	Period in Gollies*

* One golly is represented by _____ seconds.

Table 2

Prediction of Alignment

Planets Aligned	Time until Alignment
A and B	
A, B, and C	
A, B, C, and D	

Table 3

Actual Time of Alignment from Simulation

Planets Aligned	Time until Alignment
A and B	
A, B, and C	
A, B, C, and D	

Put a check in the column in table 4 that represents the number of gollies for each completed orbit.

Table 4

Orbits Completed by Planets in the Delphi System

	Number of Gollies											
Planet	1	2	3	4	5	6	7	8	9	10	11	12

DATA SHEET 3
PLANETARY ALIGNMENT IN THE SOLAR SYSTEM

Suppose that the four inner planets are in alignment.
When will it happen again?

Use a calculator to determine when the planets are in alignment. The chart on the right below shows subproblems to help you find the answer.

The alignment of all the planets would be a rare event. Can you determine how often it would occur?

	Planet	Period of Revolution
1	Mercury	88 days
2	Venus	225 days
3	Earth	365 days
4	Mars	687 days
5	Jupiter	12 years
6	Saturn	29 years
7	Uranus	84 years
8	Neptune	165 years
9	Pluto	248 years

Planets Aligned	Years or Days until Alignment
1 and 2	
1, 2, and 3	
1 through 4	
1 through 5	
1 through 6	
1 through 7	
1 through 8	
1 through 9	

DATA SHEET 4
CALCULATING PROPORTIONAL DISTANCES FOR A MODEL OF THE SOLAR SYSTEM

This ratio sets the scale for the model.

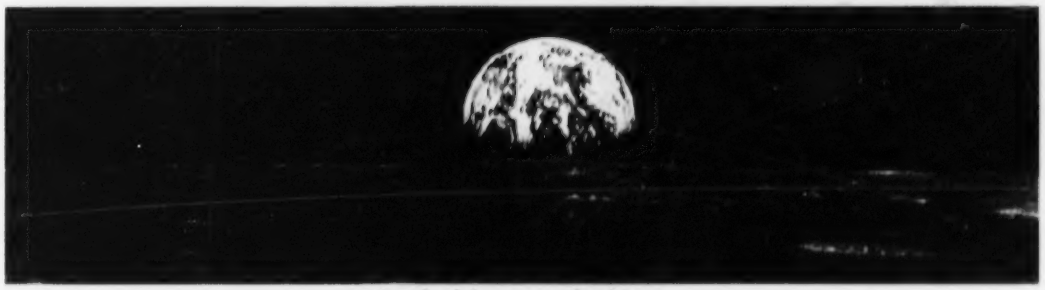
This ratio allows us to find the location of any planet in the model.

$$\frac{\text{Classroom distance from the Sun to Pluto}}{\text{Actual mean distance from the Sun to Pluto}} = \frac{\text{Classroom distance from the Sun to planet}}{\text{Actual mean distance from the Sun to planet}}$$

Planet	Actual Mean Distance from the Sun (millions of km)	Classroom Distance from the Sun	
		First Trial	Second Trial
Mercury	57.9		
Venus	108.2		
Earth	149.6		
Mars	227.9		
Jupiter	778.3		
Saturn	1427		
Uranus	2871		
Neptune	4497		
Pluto	5913		

DATA SHEET 5
PLANETARY DIAMETERS AND DISTANCES FROM THE SUN

Body	Mean Distance from the Sun (millions of km)	Diameter (km)
Sun	—	1 392 000
Mercury	57.9	4 880
Venus	108.2	12 100
Earth	149.6	12 756
Mars	227.9	6 786.8
Jupiter	778.3	143 200
Saturn	1 427	120 000
Uranus	2 871	51 800
Neptune	4 497	49 528
Pluto	5 913	~2 330



Earth rising over the Moon

RELATIVE SIZES OF THE SUN AND PLANETS

THE 1000-YARD SOLAR SYSTEM: SAMPLE STUDENT DATA

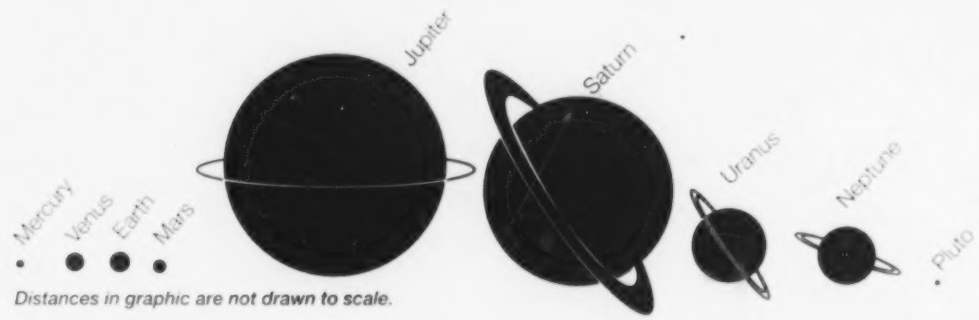
Body in the Solar System	Number of Paces from the Previous Body	Number of Cumulative Paces from the Sun**	Object
Sun	0	0	Bowling Ball
Mercury	10	10	Pinhead
Venus	8	18	Peppercorn
Earth	7	25	Peppercorn
Mars	14	39	Pinhead
Jupiter	93	132	Pecan
Saturn	109	241	Hazelnut
Uranus	244	485	Coffee Bean
Neptune	275	760	Coffee Bean
Pluto	240	1 000	Pinhead*

Every pace (one yard) equals approximately 3 672 000 miles.

* Try to find a smaller pinhead for Pluto than those for Mars and Mercury.

** The distances represented by the numbers of paces are based on the mean distances of the planets from the Sun.

THE PLANETS AT A GLANCE



Distances in graphic are not drawn to scale.

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Mean Distance from the Sun									
Millions of Kilometers	57.9	108.2	149.6	227.9	778.3	1 427	2 871	4 497	5 913
Millions of Miles	36	67.2	93	141.5	483.3	886.2	1 782.9	2 792.6	3 672
Period of Revolution	87.9 days	224.7 days	365.3 days	687.0 days	11.86 years	29.46 years	84.0 years	165.0 years	248.0 years
Period of Rotation (in Earth time)	58.9 days	243 days retrograde	23 h, 56 min	24 h, 37 min	9 h, 55 min	10 h, 40 min	17 h, 12 min retrograde	16 h, 7 min	6.39 days retrograde
Inclination of Axis	0.0°	177.2°	23°27′	25°12′	3°5′	26°4′	97°55′	28°48′	120°
Inclination of Orbit to Ecliptic	7°	3.4°	0°	1.85°	1.3°	2.5°	0.8°	1.8°	17.1°
Eccentricity of Orbit	0.206	0.007	0.017	0.093	0.048	0.056	0.046	0.009	0.248
Equatorial Diameter									
Kilometers	4 880	12 100	12 756	6 786.8	143 200	120 000	51 800	49 528	~2 330
Miles	3 031	7 514	7 921	4 215	88 927	74 520	32 168	30 757	~1 447
Atmosphere	Essentially none	Carbon dioxide	Nitrogen, Oxygen	Carbon dioxide	Hydrogen, Helium	Hydrogen, Helium	Hydrogen, Helium, Methane	Hydrogen, Helium, Methane	Methane + ?
Number of Satellites	0	0	1	2	16	18+ (?)	15	8	1
Number of Rings	0	0	0	0	1	1 000 (?)	11	4	0

For further explanation of some of the concepts and relationships in this chart, refer to the *Mission Mathematics: Grades 9–12* poster on orbits.

THE SPEED OF LIGHT

Looking at stars in the heavens allows us to see into the past. Photons from the visible spectrum of light emitted from distant stars travel millions and millions of miles to reach our eyes. The journey takes a long time. Thus, we are seeing a particular star where it was and how it looked when the light left the star. By seeing the star as it was, we are looking into the past.

A light-year is the distance that light travels in a year. At about 186 000 miles per second (about 300 000 km/sec), light travels approximately 5.8 trillion (5.8×10^{10}) miles in a year (9.46×10^{10} km/yr). Thus, the light that leaves a star that is 415 light-years from Earth will travel 415 years to reach our eyes. We are seeing the star where it was and how it looked 415 years ago. The constellation Pleiades, or the Seven Sisters, is approximately that distance from Earth. So as we watch the evening skies for Pleiades, we are looking back 415 years in time.

As we look at the heavens with the naked eye, even in optimal conditions, we can see only about three thousand stars. Binoculars allow us to see more, and with a medium-sized telescope, we can see hundreds of

The Eagle Nebula

thousands of stars. Large observatory telescopes open the vista to millions of stars. However, the same atmosphere that sustains life and protects us from radiation emanating from outer space also hinders our view of the heavens. That is why the larger telescopes are often mounted high on mountains. The remoteness ensures that no artificial light will reduce visibility, and the atmosphere is thinner at higher altitudes.

To make observations of the heavens with less interference from the atmosphere, scientists have used instruments in balloons, airplanes, sounding rockets, satellites, and the Shuttle orbiter. Longer-term and more-powerful observations of distant objects in the universe were made possible by the launching of the Hubble Space Telescope (HST). This space-based telescope was launched from the Space Shuttle *Discovery* in April 1990. Flaws in the primary mirror of the HST limited early observations. But even the early images provided scientists with new data to study the universe. In 1993, NASA astronauts on the Hubble Servicing Mission made corrections to the mirror and other adjustments to improve the performance of the HST. This first servicing mission allowed the collection of images from space that have been absolutely spectacular. We have looked deeper into space and thus further back into time, thanks to the HST instrumentation.

The HST image on page 47 shows three columns in the Eagle Nebula. A nebula is a cloud of interstellar gas and dust. The term *nebula* was coined to describe objects in space that appeared fuzzy when viewed through early ground-based telescopes. The Eagle Nebula is located in the constellation Serpens, the Serpent, alongside the southern Milky Way. It is approximately 7 000 light-years from Earth. Thus, the images we see of the Eagle Nebula show us how the nebula looked 7 000 years ago. This is an example of how the HST allows us to look further into the history of the universe.

The Coma Cluster

In a wider view, the HST image on this page shows a cluster of galaxies called the Coma Cluster. Although the Coma Cluster includes one thousand large and thousands of smaller galaxies, only hundreds of galaxies can be seen in this picture of a portion of the cluster. Some of the more easily identified ones are a large, bright, nearly circular galaxy, a spiral galaxy on the upper right side, and, near the center, two colliding galaxies. This galaxy cluster is located 300 million (3×10^7) light-years from Earth.

MODULE
HOW FAR CAN I GO IN 8 SECONDS?

Module Mission

To explore the potential of travel in space through hands-on activities that develop students' concepts of average rate of speed

To use computation, estimation, and algebraic reasoning to develop students' understanding of the immense problem of distance in space travel

Space travel is an idea that intrigues the young and the old alike. Can we go to other planets? Can we travel at "warp speed"? Thinking about space travel allows the imagination to run wild. This module addresses some of the difficulties of space travel. Students use important mathematics to develop an understanding of large distances, time, and average rate of speed. There are some links in the lessons of this module to activities and lessons in the module "Take a Spin." Teachers are encouraged to intermingle the lessons of these two units if students' interest in the topic leads in that direction.

NCTM Mathematics Standards

Number and Number Relationships

Computation and Estimation

Algebra

Geometry

Statistics

Measurement

INTRODUCTION

Only three lessons are used in this module. However, these activities can span from six through nine class periods. Some portions of the activities are optional; extensions can be done for the activities according to students' interests and abilities. There are options for the assessment activities. These activities need not be used on sequential days. Teachers can do one or two activities a week as time allows.

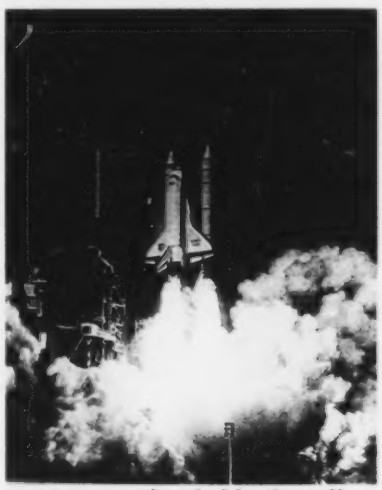
- "Finding Our Top Speed": Students determine the length of time it takes a student to walk a given distance. After collecting several types of data, students use graphs to think about the meaning of the data. In one instance, they enter data on a graph of distance at a constant time. This graph allows students to think about the slope as a representation of the speed. The "steeper" the slope is, the faster a student has walked.

- "An 8-Second Trip": In this lesson, students explore the concept of speed using familiar objects (toys) and apply this new knowledge to well-known means of transportation, including the Space Shuttle. This lesson has a great deal of flexibility.

  Three experiences with toys are presented. Doing all three activities is the best alternative. However, if the lack of time or materials poses a problem, students will profit from any of the hands-on experiences that can be done. Experiences with the speed of toys make the concept of speed applied to real modes of transportation more meaningful.

- "Travel in the Solar System": This lesson focuses on human travel in space. The distances from one planet to another are considered in relation to the time required for humans to reach the planets for exploration. Students use estimation, computation, and algebraic reasoning as they consider the time required to travel to a planet and then return to Earth. This lesson has obvious links to the "Take a Spin" module. Students may want to "loop back" into the earlier unit to refine their thinking. This backtracking should be encouraged if students' interest in space is high. Some mission teams may have an interest in going back to "Take a Spin" when others do not. Teams and individuals should be encouraged to reflect on their learning in earlier activities.

The lesson "An 8-Second Trip" requires advance preparations and approval from the school administration. Materials for the activities must be sought long before the module is initiated. Advance planning for the use of the material is



A Space Shuttle blasting off

NCTM Teaching Standards:

Teachers should provide and structure the class time necessary to explore sound mathematics and grapple with significant ideas and problems.

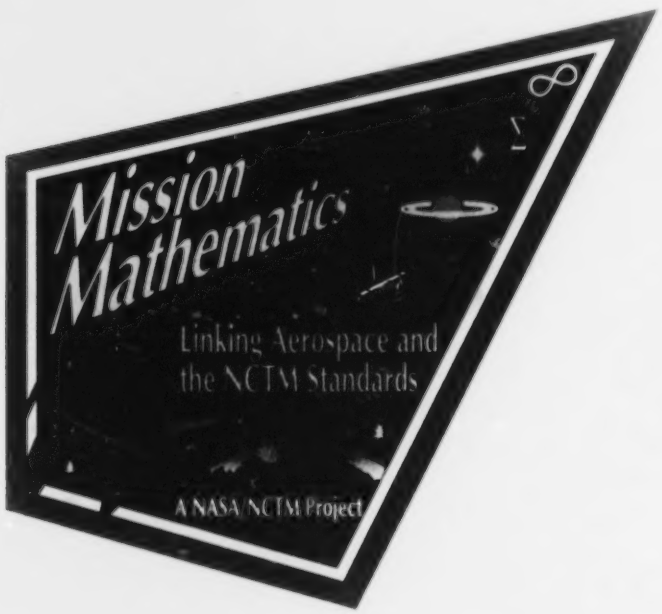
(NCTM 1991, p. 57)

BEST COPY AVAILABLE

necessary for a successful lesson. Establishing stations for the materials is one strategy for doing all three activities if materials are limited.

Students formulate their thoughts and write about their learning throughout the module. The log-book form of journal writing allows students to express their understanding of mathematics, construct the meaning of previously encountered concepts, and internalize learning. The log books are the vehicle for students to record their mathematical understanding as well as their understanding of space science.

Creating mission patches and log-book covers are important parts of the learning in this unit. Some students can express geometrically their understanding of mathematics applied to space science. The design and production of mission patches and log-book covers give students whose use of spatial sense is high an avenue to communicate and internalize learning. In making the patches and log-book covers, they should be encouraged to portray how mathematics is important to the activities in the unit.



LESSON 1
FINDING OUR TOP SPEED

Mission

To determine the length of time needed to walk or run a given distance and to plot the data on a graph

To determine the distance walked in 8 seconds and to plot the data on a graph and then use the results to develop the concept of slope

NCTM Mathematics Standards

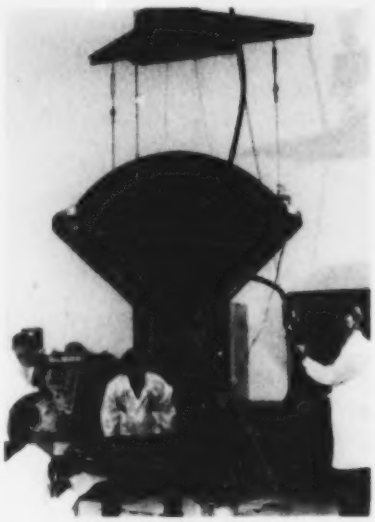
Measurement

Statistics

"Are we there yet?" "How much farther?" These frequent questions of students on a long automobile trip indicate their poor concept of the passage of time and of distance related to time. This lack of understanding carries over into students' concepts of time and travel in space.

In December 1995, the probe that had been released by the *Galileo* spacecraft in July 1995 entered Jupiter's atmosphere. *Galileo* had traveled 2.3 billion miles since its launch in October 1989. It spent the first 3 years in the inner solar system. During one flyby of Venus and two flybys of Earth, it gathered enough velocity from the gravity of the planets to reach Jupiter. Throughout its long journey, *Galileo* has been sending data about solar system back to Earth.

Studying the passage of time and time versus distance, students are better able to think about the time required to travel the long distances in space. Of course, the long time required for this type of travel is exactly why it is difficult for humans to make journeys to the planets. "Are we there yet?" This query really has meaning for space travel. Remember, *Galileo* traveled for more than 6 years *one way* to get to Jupiter.



Scientists working on the Galileo space probe

PURPOSE

This lesson sets the stage for a discussion of travel in the solar system. By considering a real-world, hands-on activity, students develop their understanding of time and distance. The mathematics necessary for the lesson relates to measuring time and distance as well as graphing to portray the data collected.

NCTM Teaching Standards: ***The teacher of mathematics should orchestrate discourse by—***

- ***posing questions and tasks that elicit, engage, and challenge each student's thinking;***
- ***deciding when to provide information, when to clarify an issue, when to model, when to lead, and when to let a student struggle with a difficulty.***

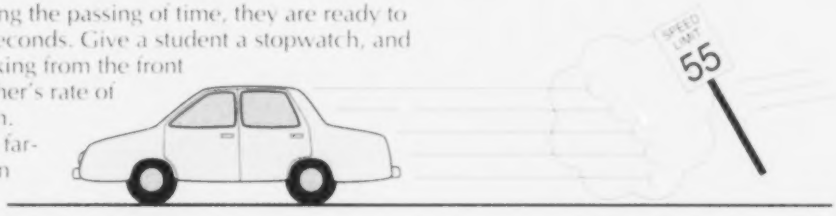
(NCTM 1991, p. 35)

GETTING STARTED

Start the lesson by asking the students how far they can go in 8 seconds. Typically, students answer in a variety of ways. Some respond with distances from a few feet to the length of a football field. Others ask, "Are we traveling by foot, on a bicycle, or in a car?" Confine the discussion at this point to travel on foot.

The passing of time is a difficult concept for everyone. In certain settings, when we are enjoying ourselves, time seems to fly by; in other contexts, time seems to stand still. To help students develop their sense of time in a neutral context, ask them to close their eyes. Tell students when to start, and ask them to raise their hands after exactly 1 minute has passed. Practice with estimating the passing of time improves performance. Ask students to share the techniques they used to guess about the length of a minute. Let students practice with time intervals less than a minute. Conclude this activity by estimating the duration of 8 seconds.

After students have practiced estimating the passing of time, they are ready to see how far a teacher can walk in 8 seconds. Give a student a stopwatch, and have him or her time the teacher walking from the front to the rear of the classroom. The teacher's rate of walking might be a topic of discussion. Students often feel that they can walk farther than the teacher because they can walk faster.



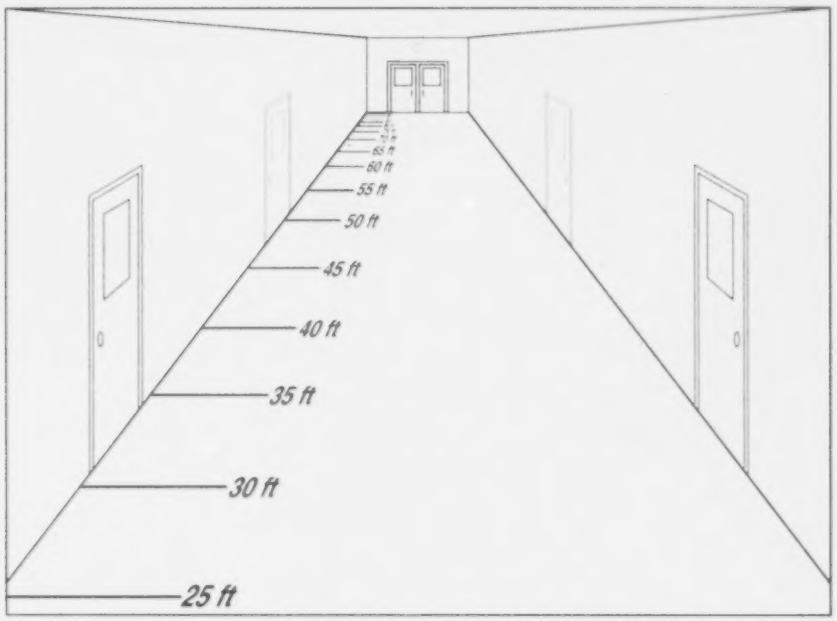
BEST COPY AVAILABLE

Part A

DEVELOPING THE ACTIVITY

Materials: ***Yardsticks or 50-foot measuring tape, stopwatches, graph paper, index cards, and masking tape***

To gather data about their walking speeds, students mark off in a school hallway or outdoors distances from 25 feet to approximately 100 feet in increments of 5 feet. Mark the intervals with masking tape. Have each student carry an index card that has his or her name and lines for recording as many trials as you intend to do.



A school hallway marked off in 5-foot increments

For this first experiment, everyone walks 100 feet, and the timers tell students the time each took to complete the distance. Each mission team takes a turn timing another team.

Line up students and begin the trials. The teacher tells members of a mission team when to go. Three students should have stopwatches to time each walker. The time recorded is the median of the three times shown on the timers' watches. Using multiple timers avoids losing data because of difficulties using a stopwatch. If sufficient stopwatches are not available for this scheme, have each timer pick a participant and keep time for that student. Some students may need to repeat their walks if a timer makes a mistake.

CLOSING THE ACTIVITY

To facilitate making a graph of the class data, have each student record her or his time on the reverse side of the index card in large writing. Begin by making a graph of the class data using the students themselves. Ask five students to come to the front of the room and stand in order according to their times, from the least to the greatest. Ask another group to come to the front and put themselves into the ordered group. If the times are the same, the students should stand behind one another. When all students are in the ordered group, the graph is complete.

The teacher should record on the chalkboard or an overhead transparency a frequency table for the "human" graph. When seated again, each student should make a bar graph of the data in the frequency table.

Part B

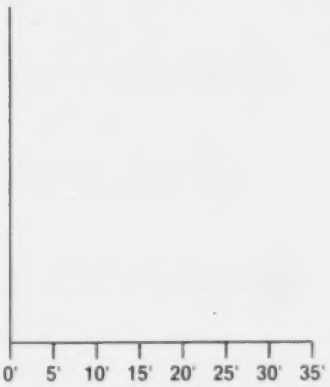
DEVELOPING THE ACTIVITY

The next phase of this lesson requires students to collect data about how far they can walk in 8 seconds. That is, the time allowed for walking is held constant and the distance varies from student to student. The marked-off, 5-foot increments are used to measure the distances.

Only one timer is necessary. The teacher is probably the best timer here because the stop and go commands need to be authoritative.

At the stop command, each student looks at the distance markers and records the distance walked. Of course, students do not always stop on a mark. They need to agree on how to estimate the number of feet they have walked beyond a mark, add that distance to the marked distance, and record their results on their index cards.

One trial is sufficient for this activity, but multiple trials can be done. For multiple trials, use an odd number of trials and the median of the results for the final graphing activities.



Different students can walk varying distances in 8 seconds.

CLOSING THE ACTIVITY

Have each mission team record its results on one graph. The graph should show distance versus time, with distance on the vertical axis and time on the horizontal axis. Be sure to talk about the point where time is zero and distance is zero, which is also a potential data point. Connect each point on the graph (representing how far each student on the mission team walked in 8 seconds) with (0, 0). The steepness of the lines connecting (0, 0) to the data points shows the average rate of speed, or slope. Use this opportunity to discuss the concept of slope and to give a formal definition of the slope of a line.

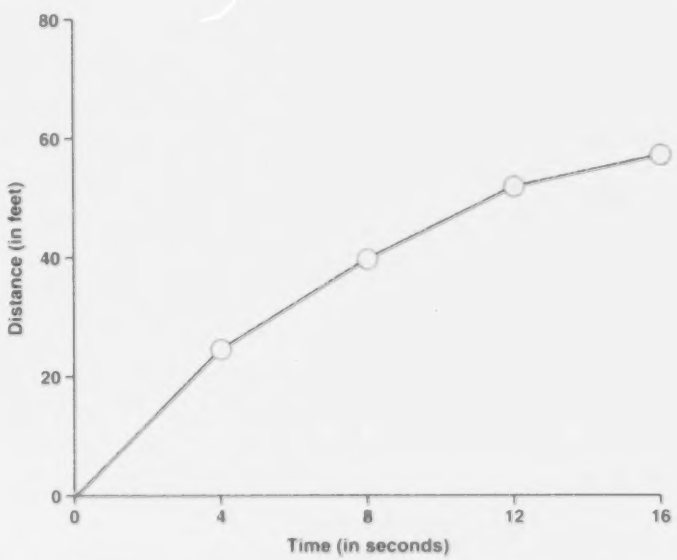
CLOSING THE LESSON

Two types of graphs and various statistical concepts are used in the lesson. Students should use their mission log books to record their thinking about these ideas.

Students make mission patches for "How Far Can I Go in 8 Seconds?" As time allows, students begin working on the visual interpretation of what they are learning. Listing ideas to incorporate into the patch design is a good activity. The list should include both mathematical and scientific ideas.

EXTENDING THE LESSON

Students may want to check their speed over longer distances to confirm that in 16 seconds they go twice as far. Note that the empirical data most likely do not show a linear relationship. As the length of time increases, the average speed usually decreases. Talk about the effects of tiring over time. If shorter times are used, the speed could be faster. Discuss that the linear graph approximates where each walker would be in the intervening times if he or she walks at a constant rate of speed. This result explains why we characterize the graph as showing the average rate of speed.



The effects of tiring show that speed decreases over time.

LESSON 2
AN 8-SECOND TRIP

NCTM Mathematics Standards

Algebra

Measurement

Geometry

Statistics

Mission

To determine the speed of various toys by conducting experiments

To calculate the speed of various means of transportation by using algebra

With car chases and thrilling airplane maneuvers in action-based movies, students have witnessed many events involving speed. In spite of this exposure, students have little experience trying to quantify speed and compare rates of speed. This lesson provides several experiments involving familiar objects from the students' world with which they explore the concept of speed. These hands-on experiences are used as a basis for increasing students' understanding of the speed of conventional modes of transportation.

The Speed Demon rocket car can attain speeds of up to 300 miles per hour. (Photo courtesy of Brent McNeely, Hell on Wheels, Inc.)

PURPOSE

The goal of teaching mathematics is to help students gain mathematical power. They need experiences using mathematical reasoning, solving problems, and making connections to the real world. In this lesson, students explore the concept of speed as it relates to travel in space. The mathematics of this topic is rich. Students use algebra, measurement, geometry, and statistics to improve their understanding of speed.

Part A

GETTING STARTED

NCTM Teaching Standards:

Teachers of mathematics should pose tasks that are based on—

- ***sound and significant mathematics;***
- ***knowledge of students' understandings, interests, and experiences;***
- ***knowledge of the range of ways that students learn mathematics.***

(NCTM 1991, p. 25)

In lesson 1 of this module, students learned how far they could move in 8 seconds. During the opening discussion, some students may have talked about traveling at high speeds in cars and airplanes. From students' suggestions, list ways to travel fast. This list will probably contain several types of automobiles and airplanes as well as other vehicles. Consolidate the list by considering only large categories, such as bicycles, motorcycles, cars, airplanes, and jet airplanes. The Space Shuttle can be a category in itself.

Continue the discussion by asking students to recommend some miniature test vehicles, since the speed of jet airplanes and cars cannot be tested in the classroom or around the school.

Usually every classroom contains a few students who collect small toy cars that come with ramps and loops. Other students may own battery-powered remote-control cars. Some may have experimented with small toy rockets. Some or all of these vehicles can be used in and around school to help students collect data about speed.

Teachers of mathematics should promote classroom discourse in which students use a variety of tools to reason, make connections, solve problems, and communicate.

(NCTM 1991, p. 45)

DEVELOPING THE ACTIVITY

This lesson is most effective if students have an opportunity to collect and organize data about the speed of familiar objects. This experience will be valuable before they consider automobiles, airplanes, and other means of transportation from the adult world. Specific directions for toy cars, remote-control cars, and small toy rockets follow. Do as many of these activities as possible.

Toy Cars

Toy cars rolling down a ramp may not remain in motion for 8 seconds. Students need to time the cars and calculate the speed of the cars using the formula $d = rt$, where d = the distance traveled, r = the average speed of the car, and t = the time traveled. The average rate of speed (r) can be calculated by manipulating the time-distance-rate formula algebraically.

Assemble approximately 3 feet of track. To keep the track straight, secure it to a board or strong yardstick. Elevate one end and roll a toy car down the track.

Although this lesson has "8 seconds" in the title, the stopping time for a toy car is not likely to be exactly 8 seconds. This time can be affected by the ramp's surface and other variables. Before having them break into groups, let students make a few trial runs to determine a reasonable time for the car to come to a stop. All groups should use the same time interval, for example, 5 seconds. It becomes a constant in the data.

Group the students into mission teams of four students for the collection of data. One student is the car starter, another is the recorder, and two are timers. They can rotate tasks for different trials and ramps.

Have each mission team describe its ramp with the ratio of the height of the ramp to the horizontal length of the ramp. Have students collect three to five sets of data about the car and any given ramp. They will be measuring the distance traveled over the agreed-on constant time.

Students may think that they can construct a better ramp. Allow them to make some adjustments and collect more data. To ensure comparable data throughout the class, require three ramps from each group. Each mission team should collect data on a ramp with a 1/3, 1/4, 1/5, and 1/6 ratio. Be certain that students release the cars from the same point on the ramps during the trials. It is best to mark the release point with a piece of tape to assure that this occurs. It is appropriate to have each group predict which ramp would produce the highest speed.

The data should be organized as shown below, and the average speed should be calculated in feet per second.

Sample Data
Mission Team: Green

Ramp Ratio	Trial	Distance (ft)	Time (s)	Avg. Rate of Speed (ft/s)
1/3	1	8	4	2
1/3	2	8	5	1.6

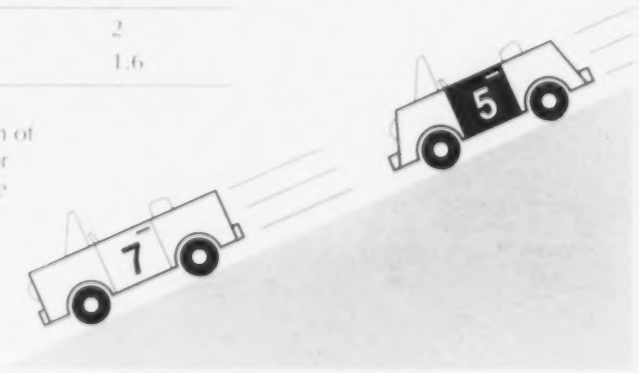
Students are accustomed to miles per hour as a description of speed. Some may want to convert the results into miles per hour because that is the only everyday reference they have for speed. Help them convert a slow speed, say, 20 miles per hour, to feet per second so they have a comparison.

To close this particular experiment, have students compare data about the ramps and the speed of the cars. Have them compare their results with the earlier predictions.

Materials for toy cars: ***At least one toy car, at least 3 feet of track for a ramp, a board or strong yardstick, another yardstick or tape measure, masking tape, and stopwatches***

Teaching Note: ***In reality, a car rolling down a ramp constantly accelerates, so the speed increases as the car nears the bottom of the ramp. The behavior of the car as it accelerates down the ramp and its behavior as it continues across the table or floor are different. Ideally, the car would travel across the table or floor at constant velocity, but its speed actually is retarded by friction. To simplify this activity for middle school students, we are determining the average rate of speed of the car.***

Teaching Tip: ***If students have reached a point in the curriculum where it is appropriate to use the Pythagorean theorem, allow them to calculate the lengths of the legs of the triangle formed by the ramp.***



Toy cars on a ramp

Battery-Powered Remote-Control Cars

Materials for battery-powered remote-control cars: ***One or more cars, stopwatches, yardsticks or measuring tape, masking tape, "traffic" cones from the physical education teacher, and extra batteries***

At least one battery-powered remote-control car is needed for this experiment. These cars come in many varieties: trucks, stock-car racers, dragsters, and so on. It is recommended that the first test of speed be done on an oval or circular track of known length. These cars can be very quick. On a straight track, the car can go quite a distance in 5 to 8 seconds. The closed track can be constructed indoors in a gymnasium, in a cafeteria, or on a stage as well as outside in the schoolyard.

Describe a track made of a rectangle with a semicircle on each end. In mission teams, the students design their own track. The students' experiences with formulas for perimeter and circumference may determine the steps they take in designing the track. Some students might develop a track shape, then measure the distance.

Alternatively, they can select a track length and then design a track with that distance. A circular track is acceptable and can be "drawn" by students using a length of string with a piece of chalk tied to the end as the radius. The track designs from all the groups should be displayed and discussed. For the first trial, the teacher should select an appropriate track for the available space. If more than one design is usable, set up more tracks to collect data. Define the track by placing traffic cones inside the track at such points as the beginning of turns and straightaways.

NCTM Teaching Standards: ***The teacher of mathematics should create a learning environment that fosters the development of students' mathematical power by using the physical space in a way that facilitates students' learning of mathematics.***

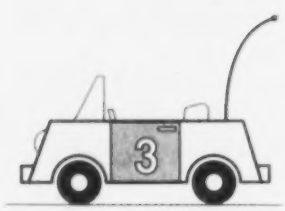
(NCTM 1991, p. 57)

To conduct the experiment, each mission team should collect data on the time required to complete one lap around the track. This time will be used to compute the average speed of the car in one lap. Members of the mission teams can play the roles of starter, timer, recorder, and driver. Each student may want to "drive." Four trials for each team may be necessary to involve all students.

The data from the experiment should be collected in a table by each mission team, as illustrated.

Sample Data
Mission Team: Blue

Track	Driver	Distance (ft)	Time (s)	Avg. Rate of Speed (ft/s)
1	Sue	54	6	9
1	Tina	54	18 (spin out)	3



A remote-control car

The closing of this activity is interesting. Because the data will vary greatly from one trial to another, a class discussion will be necessary about how to report central-tendency data from the mission teams to the class. What approach is most advantageous if the teams are competing? What result can be used to be the most consistent across teams? What data best describe the speed of the battery-powered cars? Regardless of how the data are reported, students are gaining an intuitive and formal understanding of speed through these experiments.

Toy Rockets

All rockets must be flown outdoors. The teacher must plan carefully to ensure that all safety precautions are followed. This is a time to discuss the importance that NASA places on safety and to assure the class that the same consideration will be applied in this experiment. All forms of rockets are sold with very specific directions related to construction and safety concerns. Read these directions carefully and make students aware of their importance.

Toy rockets are available in toy stores in several forms: compressed-air, water-powered, and solid-fuel rockets. It is likely that some students will own these or will have had experience flying them in a hobby club. The discussions here are based on solid-fuel rockets, since they require the most preparation and involve significant safety concerns.

The speed of rockets is more difficult to measure than the speed of toy cars because rockets are traveling vertically. Accurately measuring the distance traveled is not possible with the tools at our disposal. Most students in middle school are not ready to measure the height of an object indirectly. For the majority of students, benchmark heights, such as the school building, a tree, or the flag pole, help them estimate the height of the rocket flight. However, if this experiment is done with algebra students in middle school, they can understand the basic trigonometry necessary for indirect measurement.

In some classes, students can bring in rockets from home. In other classes, no one has rockets to share. When rockets and related equipment must be purchased, the cost prohibits each student from receiving a rocket. This experiment then becomes a whole-class activity.

Student and parent volunteers can begin building the rockets and associated equipment about two weeks before the anticipated data-collection event. This phase needs to be done only for the first school year in which the experiment is done. In later years, only replacing the fuel will be required. For the data-collection event, group students into their mission teams. All teams can collect data simultaneously. Two mission team members watch and estimate the height of the rocket flight, and two measure the time. Even with a warning about the short flights, students miss the start or forget to push the stop button on the stopwatch when the rocket reaches its highest point. Usually, one of the two students gets both tasks done. Since the time duration is very short, variance occurs in the measures of the time even if all students start and stop their watches appropriately. The jobs can rotate among team members from trial to trial. To get reasonable data, at least three rockets should be fired in each class. For both the height and the time, the two team members must agree on a value for the data chart.

Sample Data
Mission Team: Red

Rocket	Trial	Distance (ft)	Time (s)	Avg. Rate of Speed (ft/s)
1	1	60	1.5	40
2	1	75	2	37.5

Among the mission teams, data usually vary. Discuss as a whole class how to summarize the data. Make a line plot of data for each rocket and trial. Discuss how to handle data that seem to be far from the others and how to use central tendency to describe those data that seem consistent. Try to come to a class agreement on an estimate for the average speed of these rockets in feet per second. Teachers may want to to refer to *Mission Mathematics: Grades K–6* for another rocket activity, "Fizzy-Tablet Rockets." In that activity, antacid tablets are used as fuel to launch film-canister rockets. The duration of these flights is short, but it is possible to use this alternative activity to measure speed.

NCTM Teaching Standards: ***The teacher of mathematics should orchestrate discourse by deciding when to provide information, when to clarify an issue, when to model, when to lead, and when to let students struggle with a difficulty.***

(NCTM 1991, p. 35)

Materials for toy rockets: ***At least three rockets for each class, one rocket launch pad, a 12-volt battery, and stopwatches. Clinometers or hypsometers would be necessary to make indirect measurements using basic trigonometry.***

A toy rocket

CLOSING THE ACTIVITY

The closing of this part of the lesson varies somewhat, depending on which experiments are completed. However, each experiment indicates that summarizing the data should be part of the closing. Students should include these summaries in their log books along with accounts of the mathematics they used and learned in the experiments. Of course, they should record what they learned about speed from their experiments with toys. They should begin thinking about the speeds of running animals, swimming creatures, and various vehicles. Asking them to write two sentences about speed in everyday life will give insight into their present concept of speed.

Students can continue developing ideas for their mission patches.

Part B

GETTING STARTED

NCTM Teaching Standards: ***The teacher of mathematics, to enhance discourse, should encourage and accept the use of computers, calculators, and other technology.***

(NCTM 1991, p. 32)

In lesson 1, students collected data about their speed for 100 feet. Earlier in this lesson, they collected data about the speed of selected toys. These data can be entered on a class chart and discussed. The data table included on data sheet 1 on page 66 contains some data about the top speeds of some vehicles. If more data are desired about actual speed records, the *Guinness Book of World Records* (1996) may be a useful reference. Students are invited to compare the two tables. Since one is in feet per second and the other shows miles and hours, comparing the data is problematic.

DEVELOPING THE ACTIVITY

The problem at hand is how to convert the units in the data tables to allow comparisons. Since most of the earlier data are in feet per second, encourage students to convert the data on sheet 1 to those units.

40 ft/s · 60 s/min = 2 400 ft/min

2 400 ft/min · 60 min/h = 144 000 ft/h

144 000 ft/h · 1 mi/5 280 ft = 27.27 mi/h

This is a wonderful opportunity to use technology to help solve the problem. Perhaps the most appropriate technology is a spreadsheet. If the class can go to a computer laboratory where students can work independently or in pairs, the spreadsheet experience can be valuable in getting them to think algebraically.

The spreadsheet should have the following columns: Mode of Travel, Distance, Time, Distance in Feet, Time in Seconds, Speed in Feet per Second, and Distance in 8 Seconds. Students can enter the data in the first three columns from the data table. Through questioning, lead the class to propose how to convert miles to feet. Show them how to enter the multiplication of a constant, 5 280, and each number in the Distance column by using a formula. Additionally, they can copy and paste the formula throughout the Distance in Feet column.

The discussion of converting the time data to seconds involves a more complex formula. It may be appropriate to include exponents in the formula if this topic has been covered in the curriculum. Whether exponents or multiplying by 60 twice is used in the formula, both hours and minutes must be converted to seconds. Since this formula is more complex, it is most appropriate to show students how the spreadsheet's copy command is used.

This entire conversion can be accomplished without computers. The calculations can be done by using calculators or paper and pencil.

With the data table complete, students are challenged to graph the results. Expect students to find some difficulty making the graph. Because of the speed of the Space Shuttle, the range of the data is very large. The choice of a unit becomes difficult for a clumped group of data and one extreme outlying piece of data. One solution to this problem is to omit the Shuttle's speed and graph the remaining data. Look at the graph and discuss what it would look like if the data were transformed into miles per hour.

CLOSING THE ACTIVITY

Log-book writing is an important part of the lesson. First, students should write about the mathematics they have encountered and, perhaps, the technology they have used in this lesson. Additionally, students should reflect on the difficulty of putting the Shuttle's speed on the graph. On Earth, relatively little difference appears in the speed of vehicles. However, we see a quantum leap as we function in the realm of twentieth-century space travel. For humankind to travel to the outer planets and beyond, another quantum leap in our ability to travel in space will be needed.

Students should continue to develop their "8 Second" mission patches if time allows.

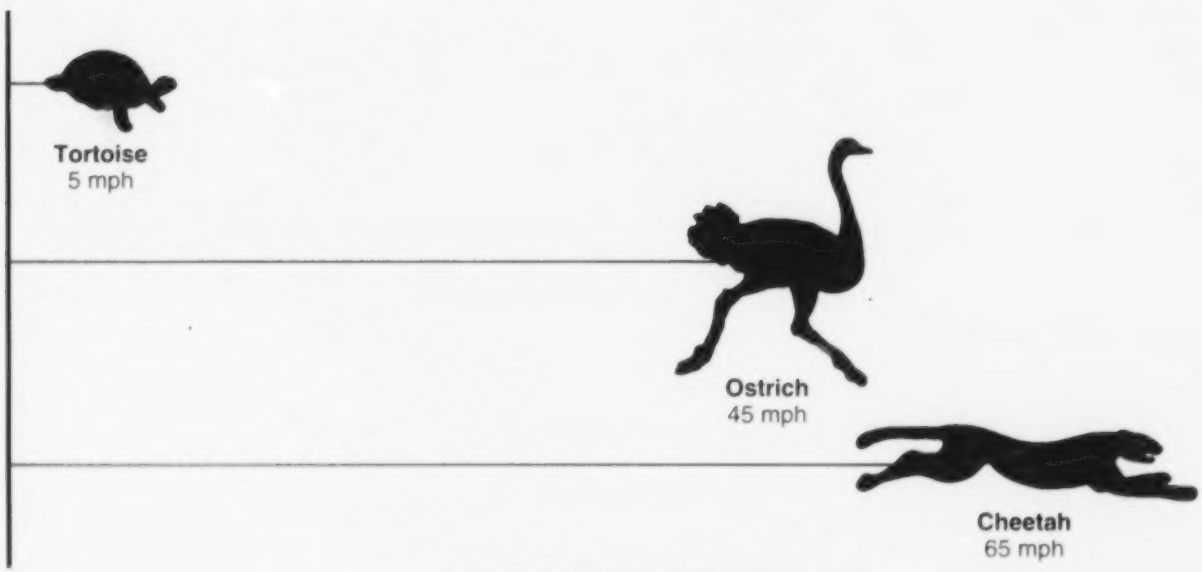
NCTM Assessment Standards:

Assessments should enhance learning. They are learning opportunities as well as opportunities for students to show what they know and can do.

(NCTM 1995, p. 13)

EXTENDING THE LESSON

Students are very often quite interested in the notion of speed, and this lesson only stimulates this interest to a higher level. Another approach to the discussion is to use the maximum speed of animals. Crawling insects, mammals of the sea, birds, fish, reptiles, and land-based mammals can all be used to develop charts of distance, time, and rate of speed. Hands-on activities related to speed can be accomplished using hamsters and turtles in classrooms. Animals can be released at the center of a circle and timed on their exit from the circle. Also, the class could have a "mutt derby" for their pet dogs. On a straight track, students can record the time for animals to complete a short race and determine the average speed of their pets.



Top speed for various animals

LESSON 3
TRAVEL IN THE SOLAR SYSTEM

NCTM Mathematics Standards

Number and Number Relationships

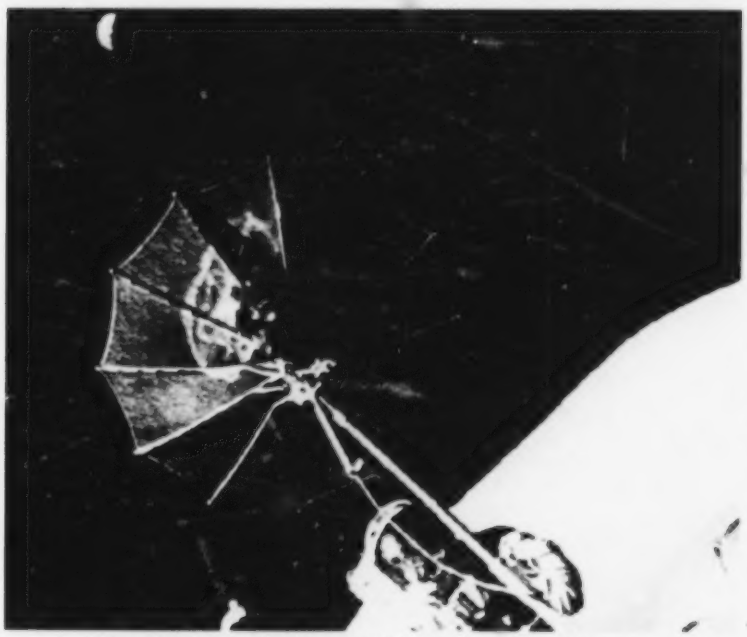
Measurement

Computation and Estimation

Mission

To apply measurement and computation to gain insight into the large numbers associated with distances in space

To plan a trip to a planet in the solar system



Astronaut on the Moon with Earth in the distance

This lesson focuses on human travel in space. One problem associated with traveling in the solar system is the distance from one planet to another. But other problems arise. A spacecraft needs fuel to make the long journeys in space, and humans need food and water throughout the long journeys. The effects of microgravity, that is, near zero gravity, on humans over time are unknown. The probability of collisions with asteroids is uncertain, and many other aspects of long manned flights make the task of space travel very complex.

However, publicity about unmanned flights to the planets continues to raise the question of humans' traveling in space. Research is required to increase the probability that prolonged space travel for humans can be accomplished safely. One of the NASA projects that will move us closer to space travel is the International Space Station, which will serve as a platform for many research agendas associated with living and working in space for long periods of time.

NCTM Teaching Standards: ***The teacher of mathematics should pose tasks that are based on sound and significant mathematics and that promote communication about mathematics.***

(NCTM 1991, p. 25)

PURPOSE

This lesson affords students the opportunity to think about two aspects of the time required to complete space travel within the solar system. First, students consider the amount of time that space travelers must spend on the journey. Second, students think about what kinds of events might occur on Earth while the space travelers are on their journey. Thinking about both situations improves students' concept of time and distance as well as improves their understanding of the solar system.

GETTING STARTED

Begin the class by engaging students in a discussion about humans traveling through the universe. In the movies and on television, students encounter science-fiction stories about traveling at the speed of light and beyond to cross entire galaxies in a matter of seconds. The activities in lesson 2 have reminded us that most of our travel speeds are quite slow. We have not come close to traveling at the speed of light. Although radio signals can return from Mars in a short time, it takes much longer for a spacecraft from Earth to reach Mars.

The Apollo 15 *module*

Distance traveled by Shuttle = 4 164 183 mi

Time to travel given distance = 9 d 23 h 30 min

$9\ d\ 23\ h\ 30\ min = 9\ d\ 30.5\ h$

$9\ d\ 23.5\ h \times 24\ \frac{h}{d} = 239.5\ h$

$\frac{4\ 164\ 183\ mi}{239.5\ h} =$

$17\ 386.985\ 39\ \frac{mi}{h},$

or approximately 174 000 mi/h

Part A

DEVELOPING THE ACTIVITY

From data sheet 1, use the data about the Space Shuttle to determine its speed in miles per hour. Remind students that the Shuttle is not designed for travel among the planets. It is designed for Earth-orbit tasks. However, its speed is helpful in judging the speeds for twentieth-century spacecraft. After students have done the calculations, come to some agreement on an approximate speed for interplanetary travel. Assume that the agreement is about 50 000 miles per hour. This figure gives us a reasonable speed to use in thinking about space travel today. In the future, speeds will undoubtedly increase.

Using the data sheet The Planets at a Glance, students can determine the distance from Earth to each of the other planets. This task is not trivial. The distances in the chart are given in millions of miles. To facilitate computation and estimation, students need to translate 67.2 million miles, the distance from the Sun to Venus, into its full numeric form, 67 200 000. Before thinking about traveling to Venus, students must remember that Earth is about 93 000 000 miles from the Sun. Use the mean distance from the Sun to specified planets to calculate each distance from Earth to the targeted planet.

To make this exploration manageable for middle school students, we are assuming that the planets are aligned at their mean distances. Teachers should explain to students that in actuality, this greatly simplified situation is unlikely to occur.

The students' next task is to calculate the time required to travel to each planet on spacecraft that travel from 10 000 to 100 000 miles per hour.

Group the students into their mission teams of four students. Ask them to complete a chart for travel to all the planets of the solar system at the speeds shown below. They should use the mean distance of each planet from Earth.

Time Required to Reach the Planets in Hours

MPH	Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
20 000								
30 000								
40 000								
50 000								
60 000								
70 000								
80 000								
90 000								
100 000								

In a typical class, students groan at the prospect of completing a chart with eighty entries. The groans provide the opportunity to challenge the teams to think of strategies for reducing the amount of calculation required to complete the chart. When patterns are used to complete entries, the teams should record them. All students in the teams should make the chart.

Discuss the patterns that teams used to complete the chart. List the patterns on the chalkboard. After all team members have shared how their patterns helped reduce their workload, ask each team how many different patterns they used.

Teaching Note: ***For students who wish to think about the relative positions of two planets in their respective orbits, teachers may wish to refer to the modeling activities in "Scaling Up" in*** **Mission Mathematics: Grades 9–12.**

NCTM Teaching Standards: ***The teacher of mathematics should create a learning environment that fosters the development of students' mathematical power by consistently expecting and encouraging students to work independently and collaboratively to make sense of mathematics.***

(NCTM 1991, p. 57)

The teacher of mathematics should pose tasks that call for problem formulation, problem solving, and mathematical reasoning.

(NCTM 1991, p. 25)

An artist's rendering of **Pluto Express**

BEST COPY AVAILABLE

NCTM Assessment Standards:

Although assessment is done for a variety of reasons, the main goal of assessment is to advance students' learning and inform teachers as they make instructional decisions.

(NCTM 1995, p. 13)

The class now has a complete chart for travel to the solar system's planets computed in hours of travel. It is time to develop some better notions of what these times mean. Pose questions that require students to think about the practicality of space travel:

- If we travel at the approximate speed of the Space Shuttle, which planets can we reach in less than 10 years?
- How fast must we be able to travel to reach Jupiter in less than 10 years?
- Traveling to some of the planets at some of the indicated speeds would take more than a lifetime, which is about 75 years. Which planets are too far away to be reached in a lifetime?
- We would like to make round trips. Traveling at 10 000 miles per hour, to which planets could we make a round trip in our lifetime?

These questions should be posed to the mission teams. The teams should discuss the questions and agree on a team response. After students begin thinking about time questions, have each mission team make up questions for the class to solve.

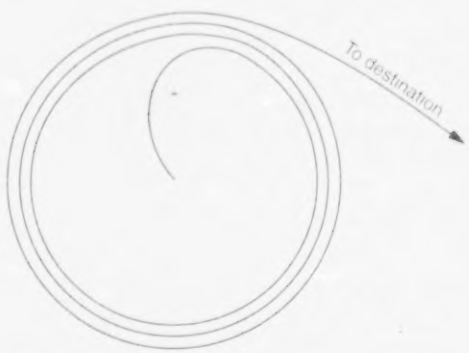
CLOSING THE ACTIVITY

Pose selected mission team questions to the entire class. The quality of the questions and the responses should indicate which students are gaining an understanding about the time required for space travel.

EXTENDING THE ACTIVITY

Teaching Tip: ***For further study, "Scaling Up" in* Mission Mathematics: *Grades 9–12 includes an activity on launch windows.***

The students who are close followers of NASA space missions may realize that this lesson simplified at least one aspect of space travel. A spacecraft is not launched directly at a planet like a bullet from a gun to a target, and the speed of a spacecraft is not constant throughout its journey. The spacecraft will most likely orbit Earth a specified number of times before using the "sling shot" effect to transfer out of orbit. This means that a spacecraft may travel much farther than the distance between Earth and its intended target. The spacecraft must take a path so as to meet a moving target, much like throwing a football to a friend who is running. The ball is thrown to where the runner will be, not where he or she is at the moment the ball is thrown. Scientists must use very sophisticated mathematics to plan long trips in space to specific destinations.



When a spacecraft is launched into space, it may orbit Earth a specified number of times before using the "sling shot" effect to transfer out of orbit.

Part B

GETTING STARTED

The terrestrial planets are the four innermost planets in the solar system: Mercury, Venus, Earth, and Mars. They are called terrestrial because they have a rocky, compact surface like Earth's. Jupiter, Saturn, Uranus, and Neptune are known as Jovian, or Jupiter-like, planets because they are gigantic planets when compared with Earth and have a gaseous nature like Jupiter's. Jovian planets are sometimes called the gas giants. Pluto is not a member of either group. Its composition is unknown, but it is probably composed mostly of rock, ice, and frozen gases.

DEVELOPING THE ACTIVITY

Present the following scenario to students:

> Since humankind wants to know more about each of our planetary neighbors, we need to plan our travel to the planets. Select one terrestrial planet and one Jovian planet. Plan trips to the two planets and to Pluto. Describe the speed of your spacecraft as well as the time required to reach the planet, stay one Earth year to explore it, and return to Earth. You may assume that advances will be made in the development of spacecraft and that speeds up to 50000 miles per hour will be possible.

Launch day for all missions is 10 December 1999. On what date will you arrive at the targeted planet? On what date will you return from each mission?

These questions will require that students convert such time intervals as 10.2 years into years and days. When the conversion results in a part of a day, round the value to the nearest day. Students may not be familiar with thinking about a date in the year as having an ordinal value in relation to the year; for example, 1 July is the 183rd day of the year. Locate a reference calendar where the ordinal value is given along with the date. Remind students they are not beginning with 1 January, however. Launch was on 10 December. Since the year 2000 is a leap year, students need to use 366 days for that year as well as other leap years spent traveling to other planets.

NCTM Mathematics Standards: ***The mathematics of the middle school should include opportunities for students to extend their understanding of systems of measurement.***

(NCTM 1989, p. 116)

There are many approaches to the solution of this task, including the use of technology. All correct solutions should be accepted. Computational solutions, graphing solutions, and technological solutions are equally valid. This is an opportunity to celebrate students' originality.

CLOSING THE ACTIVITY

Each member of the mission team should write about one of the trips to a planet. The description should include the launch date, the destination, the speed of travel, the time to reach the planet, the date of arrival, and the date the crew returned to Earth.

Each mission team should make a mission patch for one of its planned journeys. This patch can be attached to the log book for this lesson.

Part C

GETTING STARTED

To this point in the lesson, students have been considering space travel from the perspective of what happens to the space traveler on the journey. But while the space travelers are visiting distant planets, life continues on its usual course at home on planet Earth. Students should be familiar with this aspect of all travel from their previous experiences. While they are away from home, life goes on; on their return, they need time to catch up on all the news and events. Occasionally, an event occurs while they are gone that has a profound effect on them when they return.

DEVELOPING THE ACTIVITY

Return the students to their mission teams. Tell them to imagine that their team was actually sent on a mission to their selected terrestrial planet. They know their launch data and have computed the duration of their trip and the date of their return. Although NASA kept the crew members posted on the news, they have missed many important events, both personal and public.

Each mission team serves as the ground crew for a space-traveling counterpart. The ground crew's task is to debrief the astronauts on their return to Earth.

Each ground crew makes a list of important events that the astronaut crew should know about on its return. Of course, the names and some of the events will be fictitious, but they should be plausible for the time that passed on the journey. Be certain to include the results of regularly occurring events, such as elections, not just glamorous or catastrophic events. Such personal events as

Cross-Curriculum Connections: ***Students should have many opportunities to observe the interaction of mathematics with other school subjects and with everyday society.***

(NCTM 1989, p. 84)

BEST COPY AVAILABLE

graduations for family members should be mentioned, too. Sports events, such as the Olympics, the Super Bowl, and the World Series, may be important events for some students.

CLOSING THE ACTIVITY

Students present the briefings they have written for the returning astronauts. These reports could take many forms. Some mission teams may make time lines. Others may present their briefing as a newscast. They might use technology to support their presentation. Another team may make a scrapbook. Do not place limits on their creativity.

All students should take time to reflect on the mathematics of this lesson. The calendar, the time conversions, the distances in space, and the speeds required to complete space travel are all important concepts for students to think about as they construct their understanding of the world and the mathematics that describes it.

Pioneer 10

HOW FAST CAN I GO? LOG SHEET

A Space Shuttle landing

Date: _____

Mission Specialist's Name: _____

Team Name: _____

Members: _____

_____

_____

_____

_____

The things I did and the mathematics I used:

The things I found out and the mathematics I learned:

The things I wonder about and the mathematics I want to know about:

DATA SHEET 1
HOW FAR CAN I GO IN 8 SECONDS?

Complete the charts below. On a single graph of distance versus time, graph the points that would indicate the distance traveled in each mode in 8 seconds. Draw a line from the origin to each point and label the line to indicate the mode of transportation and the speed. If a computer is available, use a spreadsheet to perform your calculations.

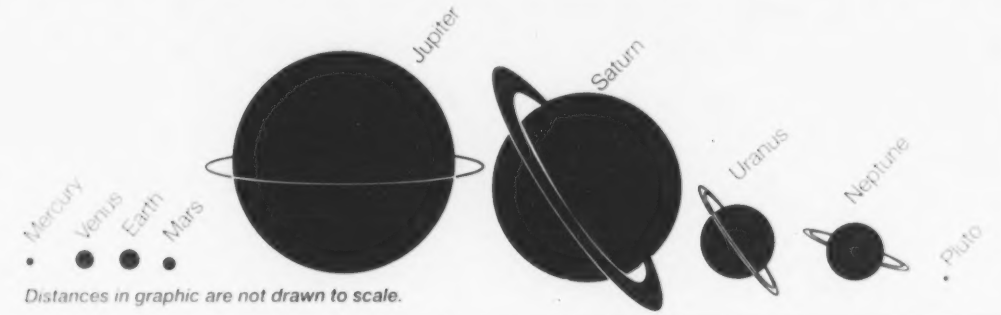
Mode of Travel	Distance**	Time**	Distance in Feet	Time in Seconds
Student*				
Bike (flying start)		0.0019 h	656.2	
Car	8 mi	45.5 s		
Rocket-Powered Three-Wheel Car	3 mi			17.11
Propeller-Driven Airplane	1.8 mi	0.0034 h		
Jet Airplane	2 982 mi	3.9236 h		
Space Shuttle	4 164 183 mi	9 d, 23 h, 30 min		

* Enter data from your classroom experiments.
** The given data indicate recognized "world records" for each mode of travel.

Mode	Speed (ft/s)	Distance in 8 Seconds
Student		
Bike		
Car		
Rocket-Powered Three-Wheel Car		
Propeller-Driven Airplane		
Jet Airplane		
Space Shuttle		

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

DATA SHEET 2
THE PLANETS AT A GLANCE



Distances in graphic are not drawn to scale.

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Mean Distance from the Sun									
Millions of Kilometers	57.9	108.2	149.6	227.9	778.3	1 427	2 871	4 497	5 913
Millions of Miles	36	67.2	93	141.5	483.3	886.2	1 782.9	2 792.6	3 672
Period of Revolution	87.9 days	224.7 days	365.3 days	687.0 days	11.86 years	29.46 years	84.0 years	165.0 years	248.0 years
Period of Rotation (in Earth time)	58.9 days	243 days retrograde	23 h, 56 min	24 h, 37 min	9 h, 55 min	10 h, 40 min	17 h, 12 min retrograde	16 h, 7 min	6.39 days retrograde
Inclination of Axis	0.0°	177.2°	23°27′	25°12′	3°5′	26°4′	97°55′	28°48′	120°
Inclination of Orbit to Ecliptic	7°	3.4°	0°	1.85°	1.3°	2.5°	0.8°	1.8°	17.1°
Eccentricity of Orbit	0.206	0.007	0.017	0.093	0.048	0.056	0.046	0.009	0.248
Equatorial Diameter									
Kilometers	4 880	12 100	12 756	6 786.8	143 200	120 000	51 800	49 528	~2 330
Miles	3 031	7 514	7 921	4 215	88 927	74 520	32 168	30 757	~1 447
Atmosphere	Essentially none	Carbon dioxide	Nitrogen, Oxygen	Carbon dioxide	Hydrogen, Helium	Hydrogen, Helium	Hydrogen, Helium, Methane	Hydrogen, Helium, Methane	Methane + ?
Number of Satellites	0	0	1	2	16	18+ (?)	15	8	1
Number of Rings	0	0	0	0	1	1 000 (?)	11	4	0

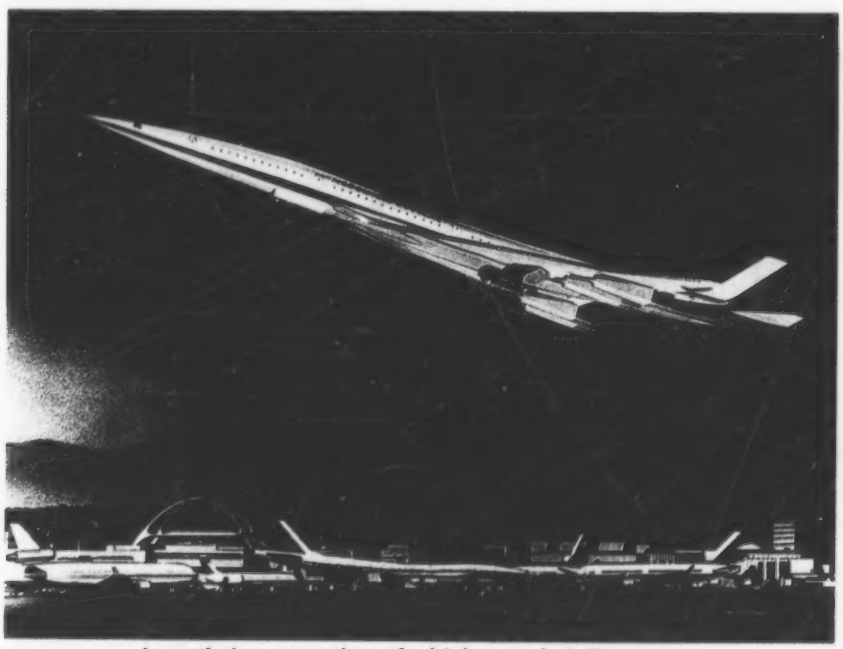
For further explanation of some of the concepts and relationships in this chart, refer to the *Mission Mathematics: Grades 9–12* poster on orbits.

An artist's rendering of an X-33 deploying a satellite

AERONAUTICS

Aeronautics is the science of flight. Aeronautical engineers solve problems and develop new concepts related to flight. NASA is a key player in this field. In NASA research laboratories and facilities today, the high-speed civil transport, high-performance aircraft, and the effects of airplanes on the environment are among many areas of study.

The high-speed civil-transport research, like many other NASA research efforts, is being conducted by a national team. NASA research centers are cooperating with manufacturers, materials suppliers, and universities in research to build a plane that will carry up to 300 passengers at speeds around 1 600 miles per hour. This plane will not be much faster than the existing Anglo-French *Concorde*, but it will carry more passengers farther because it will be more efficient. The development of the high-speed civil transport is an example of a very complex task being performed by teams of experts from many fields.



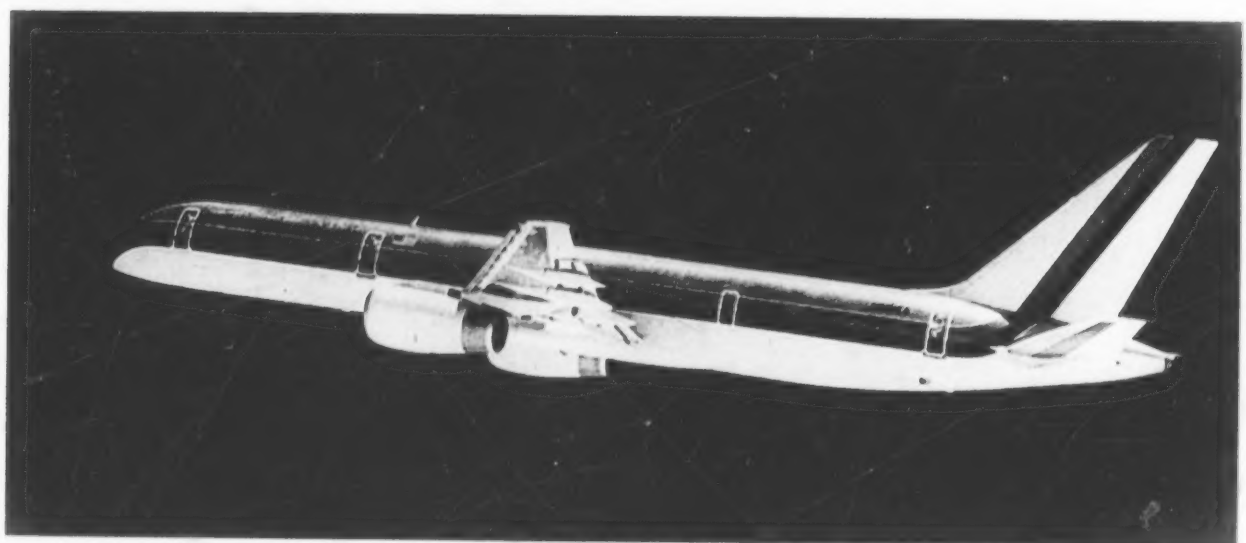
An artist's conception of a high-speed civil transport

Middle school students are beginning to think about possible careers. The field of aeronautics should be of interest to students because it shows much promise for employment in the future. The jobs involve more than engineering. Teams of scientists, engineers, technicians, computer scientists, and other support personnel are needed to solve complex problems in aeronautics and to create the technology for the next level of development in aeronautics. It cannot be emphasized enough that these professionals work together in teams in these endeavors. It is important that employees be able to cooperate to solve problems and to

have the capability of communicating their results to other teams involved in the task.

In the future, students who learn science and mathematics as well as develop the ability to work in teams may work on aeronautical problems. Some important questions facing NASA and other scientists follow:

- How do we keep aging aircraft safe for commercial flight?
- How do we minimize the negative impact of flight on the environment?
- How can the noise of aircraft be reduced?
- What techniques can be developed to predict adverse weather conditions better?
- What kinds of materials can be developed to reduce the weight of aircraft without sacrificing safety?



The 757 Flying Laboratory

MODULE
AIR OLYMPICS

Module Mission

To use concepts of measurement and geometry to build paper airplanes

To use measurement and statistics to describe the effectiveness of the airplanes built

NCTM Mathematics Standards

Geometry

Statistics

Measurement

Reasoning

Related Mission Mathematics Activities: ***In* Mission Mathematics: Grades K–6** ***are additional aeronautics activities involving paper airplanes that may be appropriate for some students.***

When you first saw—

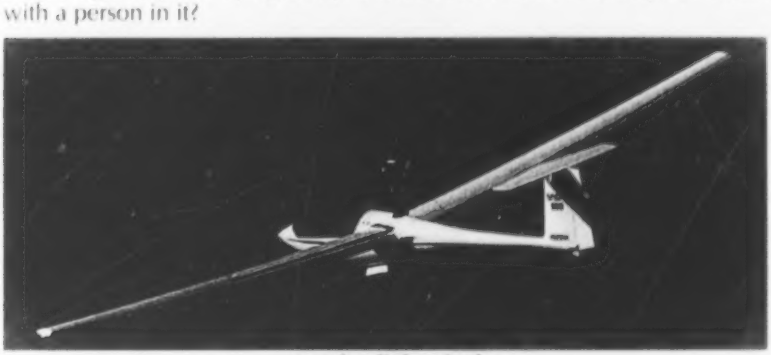
- a Boeing 747, did you wonder how such a large object could fly?

A Space Shuttle riding piggyback on a 747

- a Harrier jet land vertically, did you wonder how that could happen?

A Harrier jet

- an ultralight airplane flying, did you wonder how such a small plane could fly with a person in it?



An ultralight airplane

BEST COPY AVAILABLE

It is difficult to comprehend how these "unusual" aircraft can fly the way they do. Their existence comes from the work of aeronautical engineers, the scientists who dream a design, use mathematics and science to design an aircraft, supervise the building of the new plane, and test their designs in controlled flight testing. In this set of activities, students have an opportunity to simulate the work of aeronautical engineers.

A Blackhawk helicopter

INTRODUCTION

NCTM Teaching Standards:

Teachers should provide and structure the class time necessary to explore sound mathematics and grapple with significant ideas and problems.

(NCTM 1991, p. 57)

The "Air Olympics" module contains seven distinct lessons. These lessons can span thirteen to fifteen class periods, depending on how many optional portions of the lessons, supplementary investigations, and assessment activities are used. The activities need not be done on sequential days. Teachers and students can do one or two lessons each week as time allows.

- "Our First Paper Airplanes": Students build airplanes of their own design and from patterns.
- "Testing Conjectures about the Design of Paper Airplanes": Students make conjectures about which features of an airplane help it to perform well. They take measurements during test flights to test the validity of their conjectures.
- "Organizing and Analyzing Test-Flight Data": Students test-fly their airplanes and collect, present, and analyze data about one aspect of the performance of their paper airplanes.
- "Wind-Tunnel Tests": This optional lesson can be initiated at any time after the first models have been built. After the wind tunnel is built, it can remain as a tool for further testing and modifying of the airplanes for "Air Olympics." This lesson does require advance planning to build the tunnel.
- "Defining the Events": Students design events that are appropriate for different performance factors, such as distance, time aloft, altitude, and all-around best.
- "The Air Olympics": This activity is the culminating event.
- "Debriefing": Students summarize the results of the Air Olympics and revisit the list of conjectures about designing, building, and flying paper airplanes.

The culminating activity of this module, "Air Olympics," requires advance preparations and clearances from the school administration. Space requirements to fly paper airplanes include the use of a large room, such as the auditorium or gymnasium. An alternative site is a hallway where noise from the activity would not disturb classes. Since a class of students is actively participating, parents or other volunteers could be recruited to ensure that students remain on task during the lesson.

LESSON 1
OUR FIRST PAPER AIRPLANES

Mission

To use measurement and geometry to design, build, and test-fly paper airplanes

NCTM Mathematics Standards

Geometry

Measurement

In this introductory lesson, students begin to learn about making and flying paper airplanes. It is important for students to understand that the development of airplane designs in real life is accomplished by teams of engineers and technicians. For this reason, it is desirable to group students into mission design teams of three or four students and expert teams of seven or eight students for many activities of this module. Groups of three or four team members promote cooperative learning.

PURPOSE

This exploratory lesson sets the tone for the remainder of the module. In the process of building paper airplanes, students use the vocabulary of geometry and measurement to describe their work.

NCTM Teaching Standards: ***The teacher of mathematics should pose tasks that—***

- ***are based on a knowledge of the range of ways that diverse students learn mathematics;***
- ***promote communication about mathematics;***
- ***represent mathematics as an ongoing human activity;***
- ***promote the development of all students' dispositions to do mathematics.***

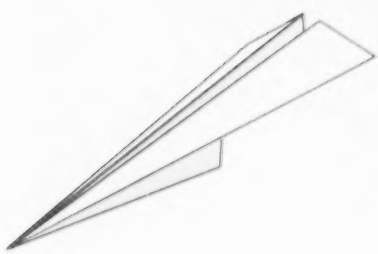
(NCTM 1991, p. 25)

Part A

GETTING STARTED

Tell the class that this set of hands-on, activity-filled investigations culminates in an Air Olympics. Explain that they will be building paper airplanes, testing the airplanes, and designing events for the Air Olympics. This information will help motivate students to do well and will serve as a brief overview of the lessons.

Form the class into cooperative groups of three or four students and call the groups design teams. After forming design teams, show pictures of flying things (kites, hot-air balloons, biplanes, jets, rockets, and the Space Shuttle) to stimulate thinking about how things fly and about the ways that people have modified "flying machines" over the years. Occasionally, recent newspaper or magazine articles can spark good ideas and discussion. See the clipping about a tailless plane on page 91.



Before building the paper airplanes, be certain to discuss basic ground rules for using airplanes in the class and emphasize the need for safety. Teachers may want to make a large poster or bulletin-board display of these rules for class reference during the activities. The following are sample rules you may wish to adopt.

Rule 1: No airplanes may fly in the classroom. All test flights must occur at specific times in designated test-flight areas. Any airplanes flown outside the areas and times will be eliminated from the competition, and their pilots will be grounded during the Air Olympics event.

Rule 2: Safety is our main concern. When airplanes are flown, all personnel will observe safety precautions. For example, safety goggles will be worn and only one plane will be in the air at a time.

DEVELOPING THE ACTIVITY

Give the following directions to students.

> In your mission design team, each of you will design and build a paper airplane that you think will fly. Each person will have one piece of paper to make one airplane. As you make the airplane, think about the folds you use so that you can tell someone else how to do it. Try to use mathematical terms, such as *triangle, rectangle, bisector,* and *symmetry,* to describe your design.

Materials: ***A log sheet for each student, 8 1/2" × 11" paper, staples, glue sticks, scissors, tape, paper clips, and rulers***

Teaching and Assessment Tip: ***By listening to students' discussion during the activity, teachers learn about the students' ability to use the vocabulary of geometry and measurement. This may help in making an informed decision about whether a review of geometry terms is needed before proceeding to part B of the activity.***

Allow time for students to make one test flight of their airplanes. Ask students to observe the test flights of all the airplanes and note the features that seem to make certain airplanes fly better than others.

Ask for several volunteers to describe how they made their airplanes. Remind them to use mathematical (geometry) vocabulary to make their descriptions accurate. The teacher should make a cumulative list of these terms on the chalkboard or other classroom display device. Once ten or more terms are listed, ask for other mathematical terms used in describing their airplanes. Reinforce appropriate use of mathematical vocabulary to communicate ideas to others.

If a master set of all mathematical vocabulary is developed, the frequency of use of each word can be noted. This can lead to a graphing exercise.

CLOSING THE ACTIVITY

Assessment Tip: ***Log books and daily journal writing are important assessment devices built into this set of activities. By reading students' responses, teachers can make better decisions about selecting and developing appropriate mathematics lessons for students.***
A sample log-book entry follows: "I was surprised how much mathematics I used to make my airplane. I have made airplanes before without thinking about mathematics. This class makes me think too much!"

For purposes of assessing the students' understanding of this activity, have them keep log sheets in their log books. Ask students to think about the mathematics they used in making their airplane. Each student should record directions for making his or her design and the design of one other student in the mission design team. Stress the use of mathematical terms, *symmetry, perpendicular, parallel, intersecting, inches,* and so on, in the descriptions.

This is the first experience in building planes, and students should record their observations about these planes. These observations should be written and could include pictures of successful airplanes. In later activities they will be asked to be more purposeful in modifying or building planes. Their log-book writings will help them through these future challenges.

Part B

GETTING STARTED

Many books have been written about paper airplanes, and designs for paper airplanes are often included in these books. Students build a model of the Boeing 757 airplane using a glider kit designed as a part of NASA educational materials. Hand out a copy of the glider patterns on pages 92–93. Each student should build this airplane. Discuss the directions. Ask students to identify the mathematical terms used in the directions. Ask them to identify places where mathematical terms could have been used when other terms appear in the directions. This large-group activity prepares them for building other paper airplanes from patterns.

The next part of the activity can be accomplished in larger groups. Students can rearrange their desks to form four "expert groups" for the remainder of the class period. To facilitate the formation of groups, have students count off from 1 to 4. Students who are "1's" form group 1, "2's" form group 2, and so on.

Each person in the group builds and flies the assigned basic paper airplane models included in this set of activities.

Expert Group 1: The Egret[1]
Expert Group 2: The Flex
Expert Group 3: The Basic Square[1]
Expert Group 4: The Condor[2]

Teaching Tip: ***Instructions are included here for only five paper airplanes. You may want to replace some or add models that are familiar to you. A number of commercial books are available with a wide variety of airplane models.***

The 757

The Egret

The Flex

The Basic Square

The Condor

The work of the expert groups may take more than one class period. In the first class period, students can complete entries in their journals as a sponge activity.

Making mission log books with cover designs and mission patches may extend the set of activities for an extra class period or more. Throughout the module, these tasks can become sponge activities to keep students on task while some groups are completing the activity of the day.

DEVELOPING THE ACTIVITY

One goal of this lesson is to use mathematical vocabulary to build paper airplanes. Some of the directions contain fewer mathematics words than others. Give the expert groups different sets of directions (the Egret, Flex, Basic Square, and Condor) to modify and improve with mathematical vocabulary as they build the plane. For example, *line of symmetry* would be more mathematically descriptive than *center line*. Have the students record the mathematics vocabulary in their log books. Then have the expert groups exchange the modified sets of directions. The members of each expert group should work cooperatively to understand the instructions and successfully build their airplanes. Each student should make five airplanes, including the 757.

Give the students an opportunity to fly the airplanes. Instruct them to observe the performance of their airplanes. Which ones fly the best? Students should record in their log books the features of the airplanes that seem to make them fly better than others. These data and those recorded from the first experience with building and flying paper airplanes will be used in later lessons.

CLOSING THE ACTIVITY

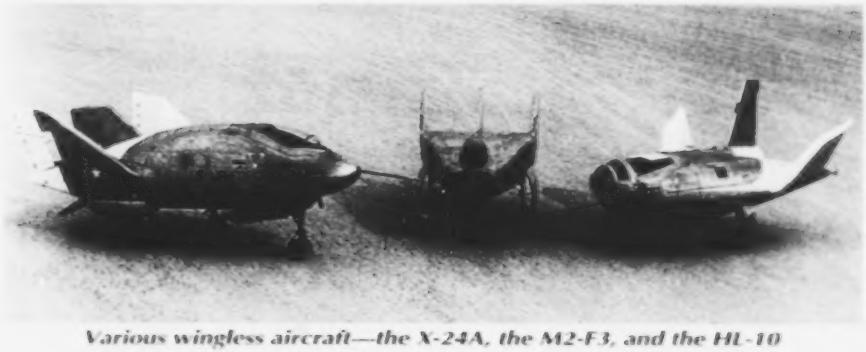
At the end, each member of the expert groups should have well-constructed models of the assigned paper airplanes.

Ask the students what mathematics words they added to the directions to make them more precise or easier to understand. Lead a large-group discussion in which students share their mathematics vocabulary and explain how the words are used in the directions. Add any new terms to the class vocabulary list. Ask the students to show what the terms mean in relation to building a paper airplane.

1 The Basic Square is used with permission of Workman Publishing Co., from *The World Record Paper Airplane Book* by Ken Blackburn and Jeff Lammers. ©1994 by Ken Blackburn and Jeff Lammers.

2 The Egret and the Condor are used with permission of Sterling Publishing Co., 387 Park Ave. S., New York, NY 10016, from *Best Ever Paper Airplanes* by Norman Schmidt. ©1994 by Norman Schmidt, a Sterling/Tamos Book.

Materials List: ***Each of the four expert groups has access to the following items: Sheets of 8 1/2" × 11" plain paper, instructions for one of the four basic models, a stapler, a ruler, scissors, glue sticks, tape (cellophane and masking), paper clips, plastic drinking straws, and log sheets (one for each student)***



Various wingless aircraft—the X-24A, the M2-F3, and the HL-10

LESSON 2
TESTING CONJECTURES ABOUT THE DESIGN OF PAPER AIRPLANES

NCTM Mathematics Standards

Geometry

Measurement

Mission

To identify design features that enhance paper-airplane performance

To collect data during test flights in order to test conjectures about the design of paper airplanes

In lesson 1, students had an opportunity to explore making paper airplanes and using their geometry vocabulary. "Testing Conjectures about the Design of Paper Airplanes" requires students to reflect on their experiences in the first activity to gather more purposeful data about the flight of paper airplanes. In the real world of aeronautical design and testing, it is not sufficient to have a good idea. An engineer must be willing to state that idea to others on the team. The idea must become public. Then the other team members demand data to verify the idea. When the idea seems like a good one, the whole design team becomes involved in collecting more data to convince others outside the team that the idea is valid. Measurement is often used as a tool to collect these data.

PURPOSE

The purpose of this lesson is to have students collect data about the design and performance of the paper airplanes that they have built. Although students should be encouraged to continue to use geometry vocabulary to describe their designs, measurement becomes a new focus in the lesson. Students must learn to describe where they have made a fold or a cut when building a paper airplane. They need to use measurement to record data about the performance of their airplanes.

GETTING STARTED

NCTM Teaching Standards: ***The teacher of mathematics should promote classroom discourse in which students—***

- ***make conjectures;***
- ***try to convince themselves and one another about the validity of their conjectures.***

(NCTM 1991, p. 45)

The initial part of the activity should be done as a whole class. A teacher-led discussion should require students to reflect on the performance of their first paper airplanes, both their own designs and the model designs.

- What features of the airplanes made them perform well?
- What was done in the process of building an airplane that made the airplane a good one?

Students should be encouraged to offer their conjectures related to the answers to these and other questions. Remember, when students offer their conjectures, they are exposing themselves to criticism from their peers. It is important to set the proper tone for the class. The successful teams are those that focus on the ideas and not on the person making the conjecture. Even those conjectures that are eventually rejected are important to the development of new knowledge about the problem. In real life, some conjectures that seemed outrageous at first have led to important discoveries, even to Nobel Prizes.

All new conjectures should be recorded on the chalkboard for the whole class and in individual log books by each student for future reference.

Materials: ***Log books, including a list of conjectures from the large-group discussion; airplanes from lesson 1; and paper, tape, scissors, and so on, for each design team (students may request stopwatches, metersticks, and measuring tapes)***

DEVELOPING THE LESSON

After the large-group discussion, students should be in their design teams of three or four people. The design teams are given three tasks:

- To use measurement to collect and record data about "good" airplanes
- To use the airplanes from lesson 1 to test conjectures from the class discussion
- To select an airplane they think is a good one and to use measurements as well as geometry vocabulary to describe how to build the plane

Once students are aware of their tasks, remind them of the rules for this module. Also, inform the teams that at the conclusion of the data collection, one team member will need to report the results of their work. They should select someone before the data are collected.

Each design team begins by selecting conjectures and airplanes to help them test the conjectures. The teacher then clears teams or members from teams to go to the data-collection area, where they can fly airplanes and take measurements about the flights. Some of the data reported should be measurements about the airplanes used to collect the data.

757 Flying Laboratory

No direction has been given about what type of measurements to make during the test flights. Some students may measure the distance of the flight, whereas others may count the number of turns an airplane makes before landing. This variety in data collection should be encouraged.

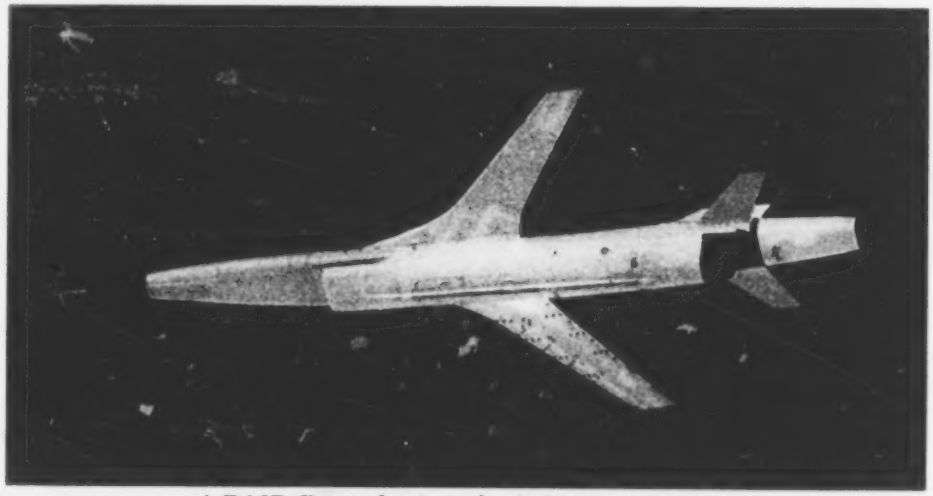
Suggestion: Limit the number of test flights to avoid confusion in the classroom and to keep within the class time limit.

After collecting data, the design teams confer about their observations and data. The discussion should end with each student on the team writing an evaluation of the conjectures he or she tested and the airplanes used to collect the data.

CLOSING THE LESSON

This part of the activity requires the whole class. The selected member from each design team should report about the results of the team's work.

Present these rules for reporting results. This is not time for a critique; it is a time for learning. Test results of one group may give insight into some conjecture or airplane design that another group had forgotten to consider.



A DAST (Drone for Aeroelastic Structure Testing)

The teacher records which conjectures were tested and what types of airplanes were used to test the conjecture. It is important to encourage the students to describe with measurements the airplanes used. Many airplanes have similar shapes but different sizes or designs.

Students are encouraged to record notes in their log books during the presentation of results.

At the conclusion of the large-group discussion, the teacher instructs students to return to their design teams. This is the time to consider the data collected by all the groups. After this small-group discussion, the members of each group are asked to write in their log books three conjectures that they think are most valid on the basis of the data they have seen and collected themselves. The students in each design team then discuss the new conjectures and agree on three new conjectures to report to the whole class at the beginning of the next lesson.

LESSON 3
ORGANIZING AND ANALYZING TEST-FLIGHT DATA

NCTM Mathematics Standards

Geometry

Statistics

Mission

To identify design features that enhance paper-airplane performance

To design and build paper airplanes

To test-fly paper airplanes

To collect and analyze data about test flights

Materials: ***A log sheet for each student, paper airplanes, stopwatches, metersticks, graph paper, an overhead projector, and measuring tapes (Students may also want to use a camcorder to record flights.)***

NCTM Teaching Standards: ***The teacher of mathematics should pose tasks that are based on—***

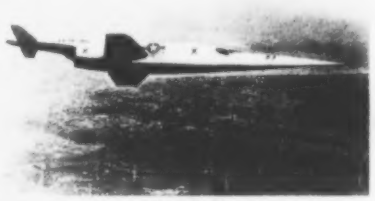
- ***knowledge of the range of ways that a diverse group of students learn mathematics;***

and that—

- ***promote communication about mathematics;***
- ***represent mathematics as an ongoing human activity;***
- ***promote the development of all students' dispositions to do mathematics.***

(NCTM 1991, p. 25)

Flight-testing experimental aircraft is a serious scientific endeavor. Aeronautical engineers at NASA design test after test to be certain that airplanes can perform consistently and safely. They test the controls, the stress on wings and rudders, the fuel consumption, the cockpit instruments, and many other aspects of the planes during test flights. They also test the plane's ability to perform. That is, how far can it fly on a full load of fuel, how sharply can it turn or dive, how much runway is needed to take off and land, and are the onboard computers capable of controlling the airplane under different circumstances?



An X-3

PURPOSE

In this activity, students fly their airplanes and collect data about airplane performance during the flights. The Test Flight data sheet on page 100 is set up for students to use line plots to record and analyze their data. Other organizing devices (stem-and-leaf plots, scatterplots, and various graphs) may require further development with students.

GETTING STARTED

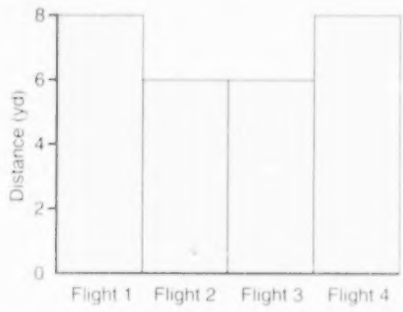
In the last activity, students made a list of conjectures that are displayed in the room and, after flying airplanes, recorded three conjectures in their log books during the lesson closing. Next, the whole class should review the list of displayed conjectures as each group reports three new or refined conjectures. The recorded list should be revised in the process of the discussion. Some conjectures will be supported and some rejected. There may be revisions or refinements to earlier conjectures, or there may be newly proposed conjectures. The spirit of the discussion should focus on sharing ideas and thinking about collecting more data to test the revised list of conjectures.

Part A

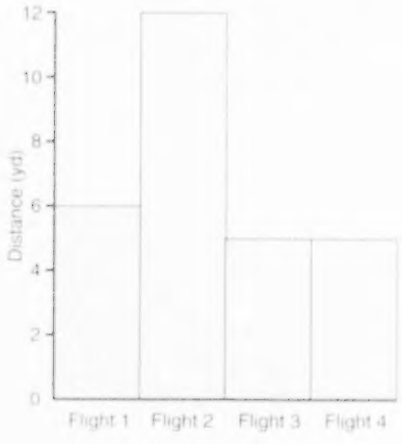
DEVELOPING THE ACTIVITY

Before students reassemble in their design teams, the teacher may find it fruitful to discuss the collection, display, and analysis of data through a sample with the whole class. The following example will stimulate students' thoughts about different types of data to be collected, how they can be organized, and the proper analysis of the data.

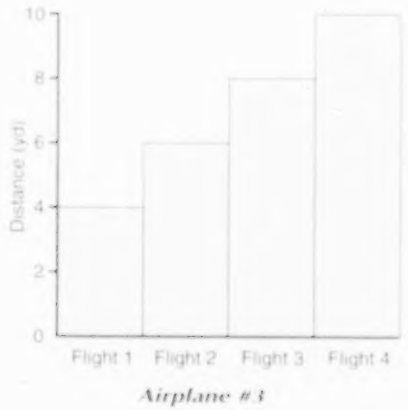
> Last year during this activity, one of the design teams collected some data that I thought I would share with you. This group was impressed by how high their airplanes could fly. They wanted to collect data about this aspect of their airplanes. They decided to use the stairway in the school hallway to record the data. As they tossed the airplanes, they recorded the number of the step where the airplane landed. The following are the data they collected and the way they organized the data.



Airplane #1



Airplane #2



Airplane #3

On the basis of these data, the design team was trying to decide which airplane would be the best for the "stair throw" event in the Air Olympics, which tests how high an airplane can fly. Let's talk about their effort.

Teaching Note: ***The discussion about the organization and analysis of data depends on the experience of the students with statistics. Since the data in the example lead the students to reject the mean as a meaningful way to evaluate the data, it is assumed that students have studied the mode and median as well as the mean.***

The data are depicted in bar graphs. Students may have studied other graphs and plots to portray data. If they have not done so, it would be appropriate to intersperse statistics lessons through this module and revisit data analysis for this activity.

Lead the discussion with such questions as these:

- What makes you think they collected good data?
- How did they organize the data in a meaningful way?
- How would you analyze the data?
- Which airplane would you select to fly in the "stair throw" event?

If data from all teams are considered, other data displays may be used. Stem-and-leaf plots would be very appropriate if the staircase has thirty or forty steps. A box plot would help the students determine paper airplanes that perform above and below reasonable expectations.

CLOSING THE ACTIVITY

Students should record the names of different ways of displaying data in their log books. A description of each type of data display should be included with the names. Students could show examples of each of the types of data display.

Part B

DEVELOPING THE ACTIVITY

Classroom Management Tip: ***Students should remain in design teams until they have an approved test plan. The teacher must approve the aspect of the airplane to be tested, the manner in which data will be collected, the type of data to be collected, and the planned analysis of the data before teams can move to testing areas.***

It is now time for students to return to design teams and collect more data about their airplanes. Students select one thing that their airplanes seem to do well. For example, their planes may fly a long distance, they may stay aloft a long time, or they may make many loops and turns before they land. Their airplanes may fly high like those in the sample data. Students should devise a way to collect data about this feature of their airplanes and test-fly them.

An X-4

The students in each design team should reflect on the test-flight data and make conjectures about which design features enhance the aspect of performance that they are testing. The students should modify their planes or design new ones and test-fly the new designs to test their conjectures.

Once test flights have been completed, the members of the design teams should record the results of their efforts in their log books. One member of each team should record the results on an overhead transparency for sharing with the class in the closing activity. Each team should display its results graphically.

CLOSING THE ACTIVITY

Each design team should report to the whole class about its test flights. Data should be shared as organized by the group. Class discussion should focus on using the vocabulary and concepts of statistics.

If the discussion of the data collected does not lead back to the list of class conjectures about paper-airplane flight, the teacher should ensure that it does move in that direction. After all design teams have reported, students should think about whether the data collected in the test flights have confirmed, altered, or eliminated any of the class conjectures. If new conjectures are created, they should be added to the class list.

LESSON 4
WIND-TUNNEL TESTS

Mission

To make and use a wind tunnel to test the effects of various design features on the performance of paper airplanes

To identify design features that enhance paper-airplane performance

To design, build, and test paper airplanes

NCTM Mathematics Standards

Algebra

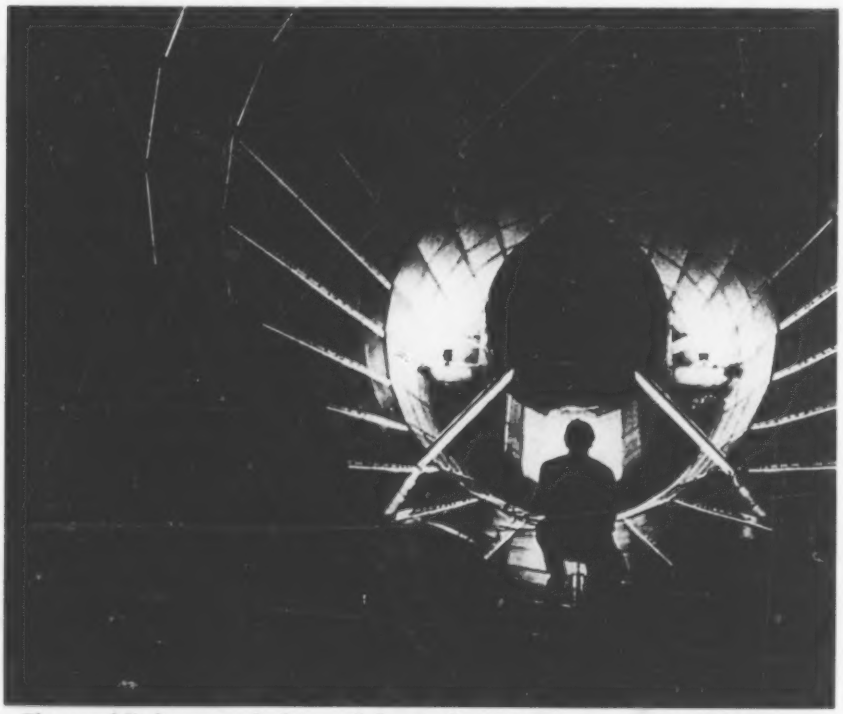
Geometry

Measurement

This activity involves constructing a wind tunnel and then using the wind tunnel to measure the wind resistance, or drag, of several objects. Be sure to read the entire lesson description and consider the availability of materials and the class time required before deciding when and how to use this activity.

NCTM Teaching Standards: ***The teacher of mathematics should pose worthwhile mathematical tasks that represent mathematics as an ongoing human activity.***

(NCTM 1991, p. 25)



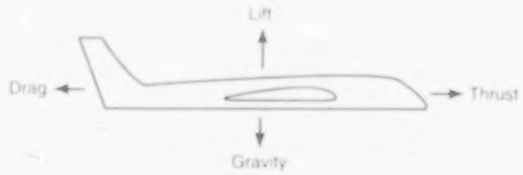
The world's largest wind tunnel, located at NASA's Ames Research Center

The use of a wind tunnel is an example of a simulation. Simulations are imitations of things that exist in the real world. Wind tunnels simulate the passage of wind over the wings of an airplane so engineers can try different designs. In NASA research, parts of planes and models of whole planes are tested in wind tunnels before an expensive aircraft is built. The world's largest wind tunnel is located at NASA's Ames Research Center in California. The facility is large enough for full-sized planes to be tested with winds up to 350 miles per hour.

Teaching Note: ***This may be an opportune time to make a connection to the science curriculum. Students may want to know how the four forces of lift, drag, gravity, and thrust relate to flight.***

PURPOSE

Students in middle school have had many experiences measuring length, weight, volume, and so on, but few have thought of a way to measure a force, such as drag. In this lesson, students make a crude gauge for measuring the force of drag and measure the force of drag on various objects and paper airplanes in a wind tunnel.



BEST COPY AVAILABLE

GETTING STARTED

Materials: ***A log sheet for each student, wind-tunnel instructions and items mentioned in the Tools and Materials list on page 101, tape, scissors, rulers, rubber bands, polyhedron nets, paper airplanes, and a window fan***

Read the wind-tunnel assembly instructions carefully (pages 101–102). Assemble the materials to build a wind tunnel. Students can play a part in the construction. In fact, if enough window fans are available, each design team can construct a wind tunnel for its own use. The construction of the wind tunnel is a good time to use the jigsaw technique of cooperative learning, in which students take on different tasks that contribute to the whole project.

Teachers should be diligent about safety during this activity. Window fans can be very dangerous. Develop strict rules about the operation of the wind tunnel, and conduct the class as if it is a research laboratory where dangerous conditions exist.

The second page of the assembly instructions presents an opportunity for algebraic thinking. Different brands of box fans have different dimensions. Consequently, a variable was used in the directions, which affords an opportunity to discuss the practical use of a variable.

Part A

DEVELOPING THE ACTIVITY

This part of the activity should be done as a large group. The teacher needs to stimulate discussion about wind tunnels. Often, some students in the class know something about the use of wind tunnels. The discussion should include historical facts as well as the modern use of wind tunnels. Students are interested to learn that the Wright brothers used crude wind tunnels to test wing design. They are equally interested to know that standard wind tunnels cannot be used to test the performance of aircraft at hypersonic speeds (i.e., greater than five times the speed of sound).

The Russian TU-144LL is a supersonic transport used in a joint research project involving NASA, a U.S. industry team, and the Russian aerospace industry.

This is an ideal time to encourage students to do some library research on wind tunnels. They can find information in the school library, or they can use telecommunications to find information within the network of NASA's Internet home pages.

Distribute wind-tunnel instruction sheets to all students. The teacher needs to go through the instructions for building a wind tunnel. For students to be enthusiastic, they must understand what they will do and what they will learn from the tunnel once it is built.

Part B

DEVELOPING THE ACTIVITY

This part of the lesson should be done in expert groups or design teams. The decision about which small groups to use depends on the number of window fans available. Students work in teams to construct the various parts of the wind tunnel. It is in this part of the activity that the jigsaw method is used. If only one window fan is available, the expert groups should be assigned to construct specific parts of the tunnel. At least one group should be assigned to make polyhedra from the nets provided.

At this point, an emphasis on accuracy in measurement is important. Wind tunnels need to be airtight to be effective. Each piece must be made carefully.

Additionally, a drag-force test gauge must be constructed. This device also requires accuracy in measurement. Lines must be straight and equally spaced to make a good instrument.

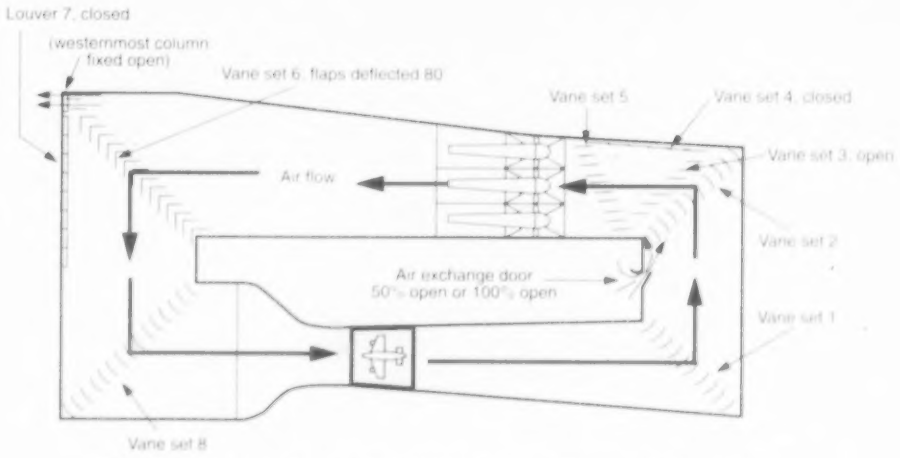


Diagram of a wind tunnel at NASA's Ames Research Center

Constructing the wind tunnel requires attention to safety. Extra adult supervision is suggested. All adults should model good safety practices, and the students should be instructed in the use of cutting devices and supervised while using such devices.

Part C

DEVELOPING THE ACTIVITY

At the conclusion of the construction phase, students reassemble into as many groups as wind tunnels constructed. If only one wind tunnel is constructed, this becomes a whole-group activity. Before students are permitted to use the wind tunnel, the teacher should lead one experiment so that all can see how to collect data about drag.

The initial experiment involves checking the drag on a tetrahedron in the wind tunnel. (See page 103 for a net to make a tetrahedron.) The tetrahedron is attached to the string at the end of the rubber band at a point where it can be seen through the window of the test chamber. Turn the fan on slow speed and increase the speed after the drag is observed. When the fan is on high speed, students read and record the amount of rubber-band stretch, using the drag-force gauge. All students should record this benchmark data in their log books.

Part D

DEVELOPING THE ACTIVITY

Next, students look at the set of polyhedra and predict which ones will have less drag than the tetrahedron and which ones will have more drag. Test the drag on different polyhedra and compare the data with the benchmark data from the tetrahedron. Students record the results of the second experiment in their log books and reflect on what the drag on various polyhedra means for the design of paper airplanes.

Polyhedra testing should be followed by paper-airplane testing. The string should be attached to the plane in such a way that the wind can flow over the wings. Students test each plane in the wind tunnel and reflect on the results of the tests to identify design features that they think may enhance the performance of their planes. The students should then modify their planes or design new ones and then use the wind tunnel to test their conjectures.

Teaching Tip: ***Throughout the process of preparing the wind-tunnel parts, the groups need to communicate with one another because in the end, the parts they are making need to match up. This is one of the values of experiencing the jigsaw method of cooperative learning.***

CLOSING THE LESSON

It is time to revisit the conjecture list. After testing all their airplanes, students may have learned something that would cause them to modify or refine the conjecture list.

LESSON 5
DEFINING THE EVENTS

NCTM Mathematics Standards

Measurement

Statistics

Mission

To create events for the culminating lesson—the Air Olympics

To develop data-collection techniques and scoring schemes for the Air Olympics events

This activity involves the development of events for the culminating activity of the module. The purpose of the culminating activity, "Air Olympics," is to allow a competitive testing of airplane designs. Although a parallel situation does not exist in the world of commercial aviation, engineers are continually creating test situations for their new designs. Test pilots fly newly designed airplanes according to very specific flight plans so that the airplanes can be tested in particular ways. The engineers decide what aspects of the plane need to be tested, develop a test, and decide how to collect data during the test.

PURPOSE

NCTM Teaching Standards: ***The teacher of mathematics should promote classroom discourse in which students try to convince themselves and one another of the validity of particular representations, solutions, conjectures, and answers.***

(NCTM 1991, p. 45)

Students simulate the testing process of aeronautical engineers with their paper-airplane designs in an Air Olympics. In this lesson, students develop the events that compose the Air Olympics. This process involves identifying important capabilities of paper airplanes and determining how to "score" the performance of the airplanes as they compete in each event.

GETTING STARTED

Materials: ***A log sheet for each student and an event specifications form for each expert group***

This activity involves some test flights to help students define their events. It may be necessary to arrange for students to use space outside the classroom so they can try out ideas about the design of events for Air Olympics.

The first task is to determine the important features of paper airplanes. The teacher should lead a discussion by asking questions about what makes a good paper airplane in terms of performance. Remind students of their previous experiences with flying paper airplanes and experimenting with the wind tunnel. The discussion often results in at least these capabilities of paper airplanes being noted:

- Some fly farther than others.
- Some stay aloft longer than others.
- Some airplanes can be controlled by the thrower.
- Some airplanes seem to do tricks (loops and turns) during flight.
- Some airplanes fly higher than others.

The Blue Angels

Students are very creative about this aspect of the activity. Once a list is brainstormed, it needs to be pared to four events through a consensus-building discussion.

DEVELOPING THE ACTIVITY

At this point in the lesson, students should be formed into their four expert groups from lesson 1. Each group focuses on the details of a single event. The first aspect of the event to consider is how to collect the data, and the second decision involves designing a scoring scheme.

It may be helpful to the expert groups to remind them of some scoring schemes used in such other events as diving, gymnastics, track, and swimming contests. Sometimes many judges are used. Often statistics (mean, median, mode) are used to summarize the judges' scores.

The challenge to each expert group is to design a good scoring scheme for a single event. Distribute to each student a copy of the Air Olympics Event Specification Form on page 107. In their groups, they discuss the various aspects of the form and come to an agreement on each part. In coming to agreement, they may need to engage in additional test flights, collect additional data, and test their scoring schemes.

Teaching Tip: ***In this part of the activity, students may want to use calculators, which should be encouraged. Calculators are tools that can be helpful in making decisions about how to score an event.***

Assessment Tip: ***Assessment practices should shift toward integrating assessment with instructional activities. By integrating statistics into this activity, the teacher can make instructional decisions that are based on the understanding of statistics shown by students.***

CLOSING THE ACTIVITY

Groups come together as a whole class. One member of each group describes its event and a scoring system for the event. These presentations initiate the discussion of the statistics used in the scoring systems.

Often students describe a scoring system without using statistics vocabulary. Use this opportunity to reinforce this vocabulary and statistics concepts. For example, students may describe a scoring scheme involving three judges that uses the middle score of the judges as the event score. This would be a good time to review the concept of median and related vocabulary.

Students should record the final agreements on event descriptions, rules, and scoring in their log books. Students should use mathematical vocabulary in these descriptions.

Air Olympics
Event Specifications Form

Expert Team Members

Event Title

Describe the event in words

Describe the rules for the event

Describe the judges who will be needed at this event and tell about their duties

Describe the equipment that will be needed for this event

Provide a scale drawing of the area needed for this event. Be sure to indicate the location of an area from which participants can safely watch, and also indicate the locations of the judges.

Describe the event in words

LESSON 6
THE AIR OLYMPICS

NCTM Mathematics Standards

Measurement

Computation

Statistics

Mission

To fly paper airplanes in the Air Olympics events the students have created

To judge the performance of other students' airplanes

Materials: ***A log sheet for each student, airplanes, tape, string, stopwatches, metersticks, measuring tapes, cameras, and camcorders***

Test flying is the time when aeronautical engineers turn the testing over to pilots. It is time to collect the final data about the performance of the test airplanes. Engineers must sit on the sidelines and wait for the data from the test flights.

Test pilot Eileen M. Collins

PURPOSE

In this activity, students act in several capacities. They are the engineers. They have a personal interest in the performance of their designs. Additionally, the students fly the airplanes. Thus, they play the role of the test pilot. Finally, while the other group is flying its planes, students measure the performance of airplanes.

This is the culminating lesson. The teacher should photograph or videotape the students as they conduct events and perform in events. Take pictures and make videotape recordings to document the student learning that has occurred in this module.

GETTING STARTED

Teaching Tip: ***It may be necessary to schedule two days for the rotations. It is important for all students to have the experience of flying airplanes and judging events.***

Students are divided into two groups, X group and Y group. Using the four expert groups facilitates developing these two groups. One group participates in the events. The other supplies the judges and officials for the events. The rotation follows:

Rotation 1: X-group members are the judges and Y-group members are the paper-airplane pilots.

Rotation 2: Y-group members are the judges and X-group members are the paper-airplane pilots.

DEVELOPING THE ACTIVITY

Teaching Tip: ***Students compute scores for each participant in each event. The accuracy of these computations using the scoring schemes devised in earlier activities is very important to each pilot. Calculators should be used for performing original calculations and checking written computation.***

Randomly assign students in the pilot group (Y group) to one of four flight squadrons. These flight squadrons rotate through the events using the following scheme:

Flight Squadron 1: Event 1, Event 2, Event 3, Event 4

Flight Squadron 2: Event 2, Event 3, Event 4, Event 1

Flight Squadron 3: Event 3, Event 4, Event 1, Event 2

Flight Squadron 4: Event 4, Event 1, Event 2, Event 3

The assignment of students in the judging group (X group) needs to be more purposeful. Each of the four judging teams should include students who are very familiar with the design of particular events.

At that point, students move to the event areas and begin Air Olympics. Parent and staff volunteers oversee the safety and operational procedures for each event. The teacher serves as the overall marshall for the Air Olympics. The role of the marshall is to resolve disputes and answer questions about interpreting the rules.

When rotation 1 is complete, students return to a whole group. The students are then redivided according to rotation 2, and Air Olympics continues.

CLOSING THE ACTIVITY

When all students complete all four events, they return to the large group. Students record their Air Olympics scores in their log book. In the next activity, the class data can be summarized by design teams from the building and testing activities.

Summarizing team data is an opportunity to have another discussion of mean, median, and mode. Since the median tends to compensate for extreme data, it is suggested that this central-tendency measure be used. Median scores often make team scores in each event very close and exciting. Ask students to begin thinking about how they can compare the results of team scores.

Assessment Tip: ***Openness is a standard in the*** **Assessment Standards.** ***In this module, students are aware of the culminating event from the first activity. Air Olympics allows students to learn the expectations for the events and the methods of scoring. This type of openness should be used in all instruction.***

A wake vortex study

LESSON 7
DEBRIEFING

NCTM Mathematics Standards

- ***Geometry***
- ***Measurement***
- ***Statistics***
- ***Reasoning***

Materials: ***A log sheet for each student and poster board for each team***

Mission

To share the summarized results from Air Olympics

To complete the list of conjectures about designing, building, and flying paper airplanes

This is the final activity of this module. In the process of developing new airplanes, aeronautical engineers would see this step as the final one of a cycle. The data from this first cycle of designing, building, and test-flying would be used to begin a new cycle. Experimental designs may require many cycles of redesign and testing. The process of developing better aircraft continues even after the experimental design reaches production. As production aircraft are carrying people and cargo, engineers from the aircraft companies collect data to improve the performance of future airplanes.

PURPOSE

In this activity, students summarize their team data and, for the final time, review the list of conjectures about paper airplanes.

In this lesson, the winners of the Air Olympics events will be recognized. Awards, certificates, and thanks will be given to all participants. The presentation of awards is time-consuming. Therefore, more than one class period may be required.

GETTING STARTED

Grouped into their design teams, students engage in a conversation about how to determine team scores.

NCTM Teaching Standards: ***The teacher of mathematics should create a learning environment that fosters the development of each student's mathematical power by providing context that encourages the development of mathematical skill and proficiency and by consistently expecting and encouraging students to display a sense of mathematical competence by validating and supporting ideas with mathematical argument.***

(NCTM 1991, p. 57)

DEVELOPING THE LESSON

Since there are four members on each design team, there are four individual scores for each event in the team scores. For each event, the following sample questions should be considered to summarize the data.

- Do we use the mean of the individual scores for the team score?
- Do we use the median of the four scores? (The median of an even number of data is the mean of the middle two data.)

Engineers discussing a design

Once team-scoring agreements are reached for all four events, students record their team results in their individual log books and on the poster board provided. The poster-board display should include outstanding individual results and the summarized team results.

Now is the time to review the conjectures that were recorded during the module. In light of the results of the Air Olympics, both individual and team, each conjecture should be discussed.

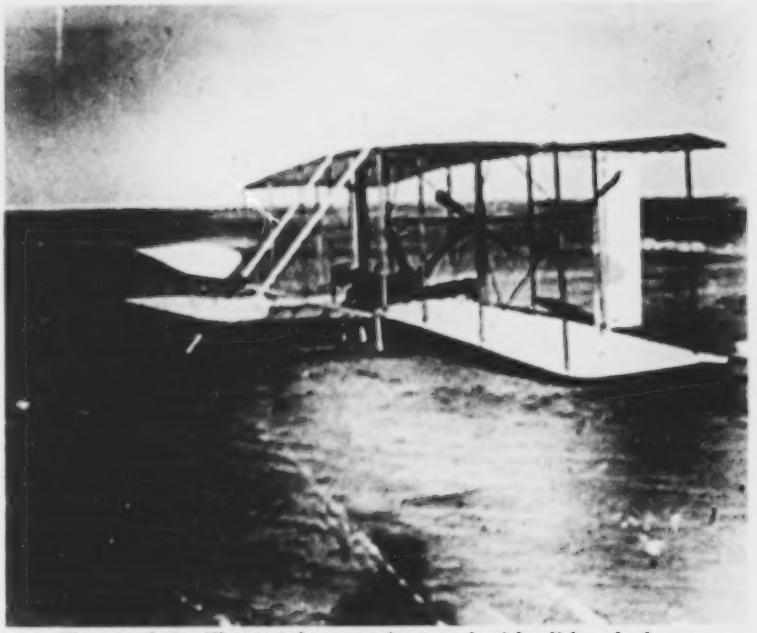
As a final assessment activity, each student should prepare a list of conjectures for the module. Some of the conjectures will be those from the class list. Some will be

modifications of those on the class list because of the discussion above. Some will be new conjectures. New learning has occurred during Air Olympics.

Students should be reminded that this activity models how progress in aeronautical engineering occurs. A continual review of the principles of flight using new materials and technology allows engineers to build bigger, safer, faster, more ecologically compatible, and more comfortable airplanes.

CLOSING THE LESSON

This is the time to recognize the "winners" of events in the Air Olympics. The awards should be consistent with school policies, of course. Although the time used to make the awards does not contribute directly to learning, the motivation for learning provided through recognition is important for all children. It is suggested that all students who compete in the Air Olympics should receive some recognition for their efforts.



Wilbur and Orville Wright experimented with gliders before building their first powered flying machine in 1903. That machine is shown above after it was damaged in the first trial of 14 December 1903. Three days later, Orville Wright flew the repaired machine on its historic first flight of 120 feet in 12 seconds. (Photo courtesy of the Library of Congress)

The Muse of Aviation trophy was given to the Wright brothers by the Aéro-Club de la Sarthe in Le Mans, France, in 1909. (Photo courtesy of the Library of Congress)

AIR OLYMPICS LOG SHEET

Date: _____

Mission Specialist's
Name: _____

Team Name: _____

Members: _____

_____

_____

_____

_____

The things I did and the mathematics I used:

The things I found out and the mathematics I learned:

The things I wonder about and the mathematics I want to know about:

Tailless Planes to Soar This Summer

Experts hope models pave the way for stealthier jets

By Michael McCabe, Chronicle Peninsula Bureau

Two small-scale models of a tailless airplane that designers hope will lead to a jet fighter far more stealthy and agile than anything flying today will be flown this summer in Southern California.

The flight tests of the remotely piloted aircraft, dubbed the X-36 by the Pentagon, are also expected to show that it is possible to build a lighter jet fighter that can fly farther, officials at NASA's Ames Research Center in Mountain View and the McDonnell Douglas Corporation announced yesterday.

Airplane designers have long dreamed of a jet that could fly without a tail, which would lead to several exciting possibilities, said Larry Birckelbaw, NASA's X-36 program manager at Moffett Field. A tailless airplane means less weight and structure, which translates into far more maneuverability and less drag. It also means less surface to be detected by enemy radar.

"This is really a breakthrough in several technologies all developed over the past seven years right here at NASA's Ames and by a strong team from McDonnell Douglas," Birckelbaw said. "We hope this will be the plane of the future."

What makes the X-36 unique is not so much that it will be tailless—the B-2 Stealth bomber does not have a tail—but that it will be far more agile and less detectable, designers said.

> 'The public has become so accustomed to a tail that they may have some discomfort climbing aboard a tailless aircraft'
>
> —Larry Birckelbaw, of NASA

One of the keys to the radical new design is that the direction of the nozzle of the main jet engine can be aimed in different directions, enabling the aircraft to fly more efficiently. The X-36 will be unveiled publicly on March 19 in a ceremony at McDonnell Douglas facilities in St. Louis.

The X-36 will be 18 feet long, have a wingspan of 10 feet and weigh 1 300 pounds. During test flights at the NASA Dryden Flight Research Center at Edwards Air Force Base the two aircraft will be powered by the same engine used in Cruise missiles. NASA officials refused to give more specifics, citing security reasons.

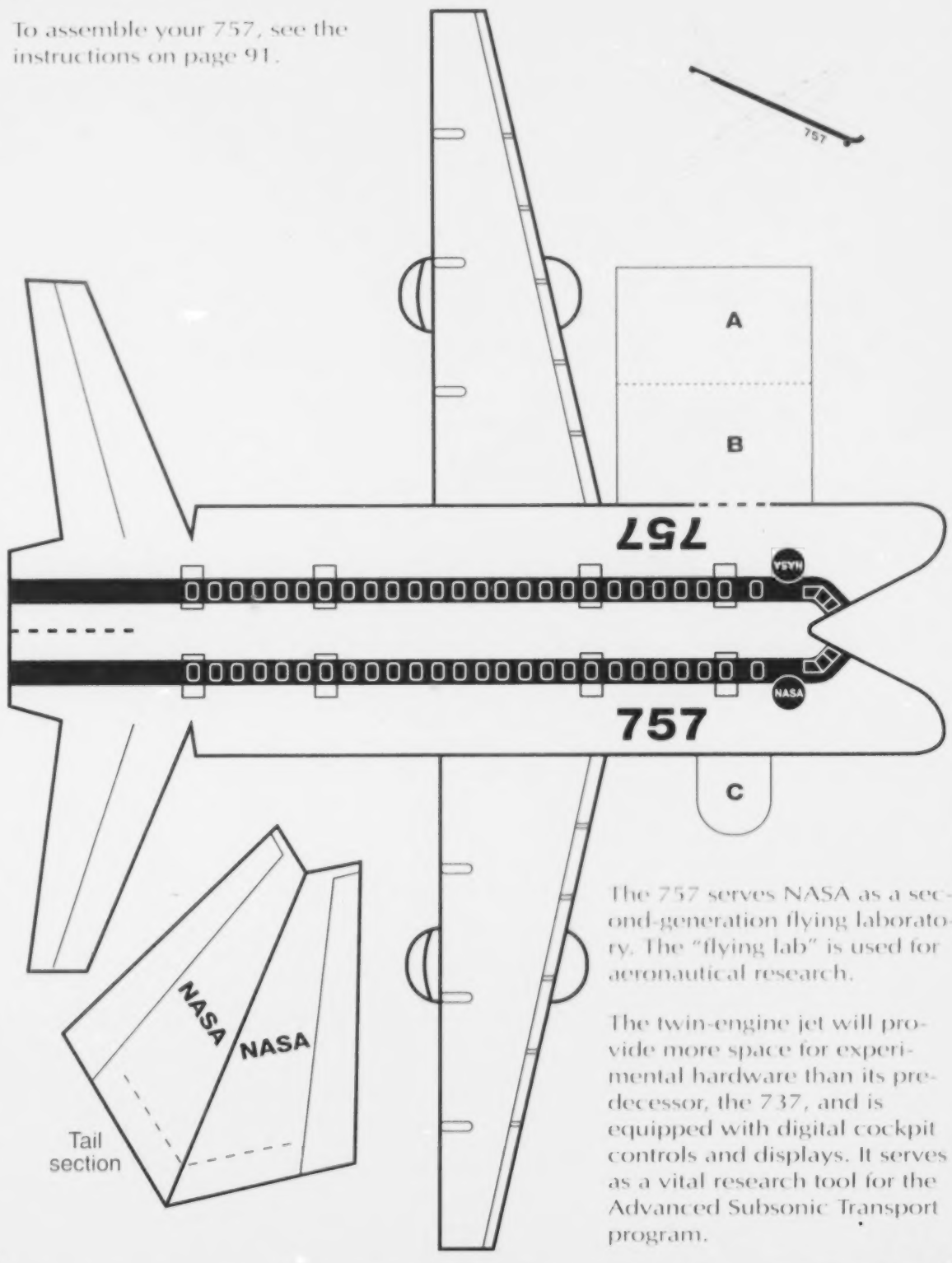
The combined cost of the program, to be roughly split by NASA and McDonnell Douglas, is $17 million for the development, fabrication and testing of the two aircraft.

Birckelbaw said it is too early to predict when the X-36 will evolve into a piloted aircraft, or even when tailless commercial airplanes may appear in the skies. But there are potential problems, mostly psychological. "The public," Birckelbaw said, "has become so accustomed to a tail that they may have some discomfort climbing aboard a tailless aircraft."

Used with permission of the *San Francisco Chronicle*. © 24 February 1996

THE 757

To assemble your 757, see the instructions on page 91.



The 757 serves NASA as a second-generation flying laboratory. The "flying lab" is used for aeronautical research.

The twin-engine jet will provide more space for experimental hardware than its predecessor, the 737, and is equipped with digital cockpit controls and displays. It serves as a vital research tool for the Advanced Subsonic Transport program.

Directions for Assembling the 757

1. Cut all the parts on both pages with scissors, and glue together the unmarked sides of the two large pieces.

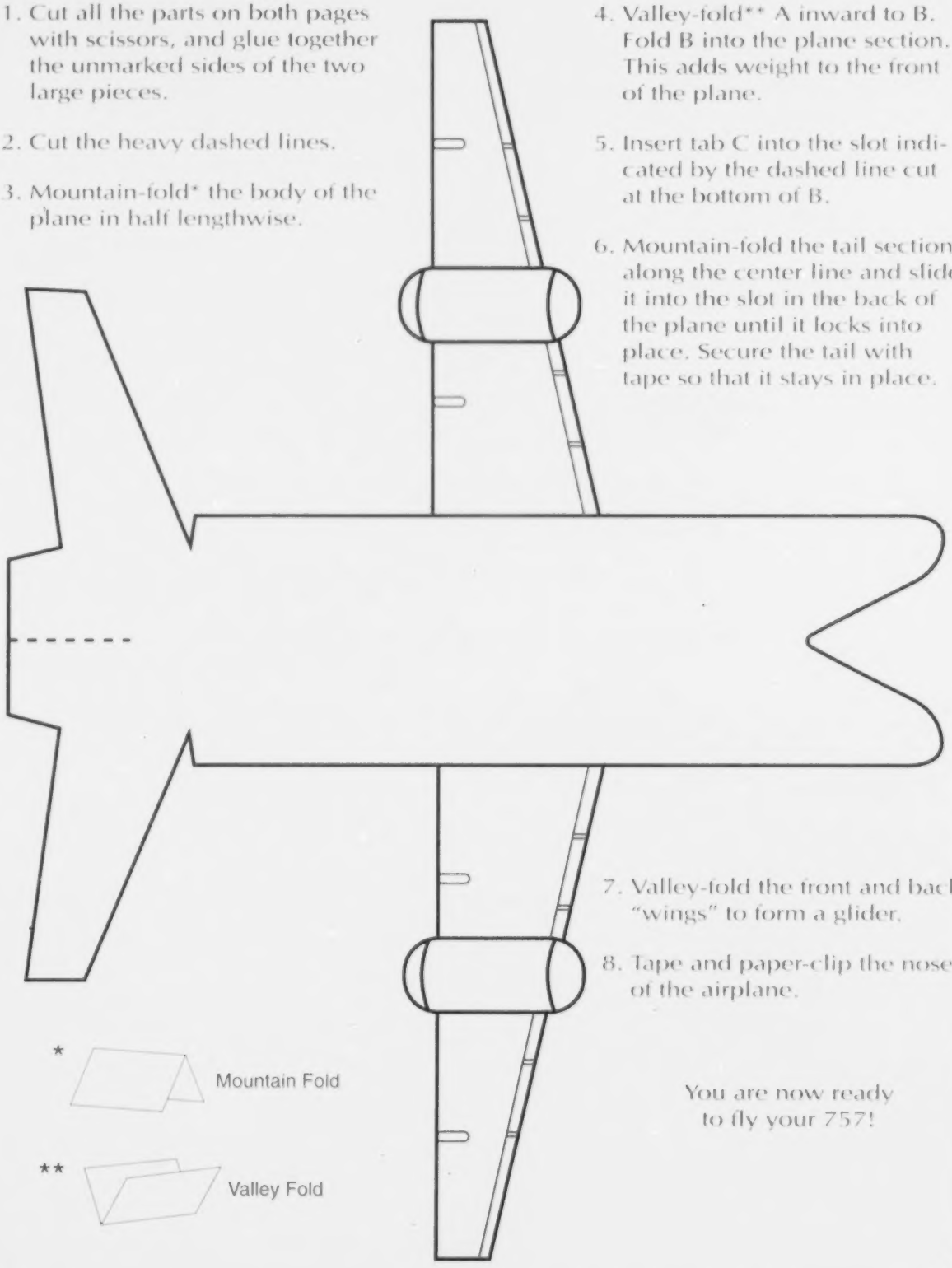
2. Cut the heavy dashed lines.

3. Mountain-fold* the body of the plane in half lengthwise.

4. Valley-fold** A inward to B. Fold B into the plane section. This adds weight to the front of the plane.

5. Insert tab C into the slot indicated by the dashed line cut at the bottom of B.

6. Mountain-fold the tail section along the center line and slide it into the slot in the back of the plane until it locks into place. Secure the tail with tape so that it stays in place.



7. Valley-fold the front and back "wings" to form a glider.

8. Tape and paper-clip the nose of the airplane.

* Mountain Fold

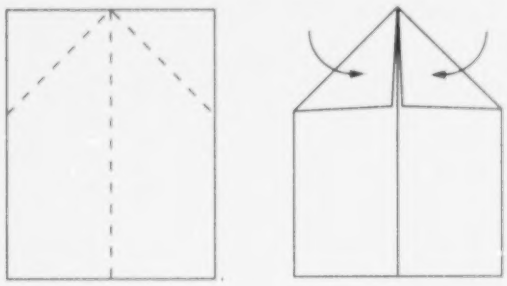
** Valley Fold

You are now ready to fly your 757!

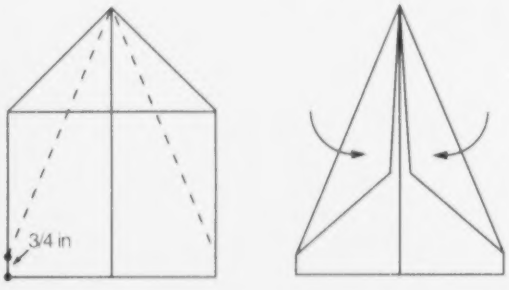
THE EGRET
EXPERT GROUP 1

Directions for Constructing the Egret

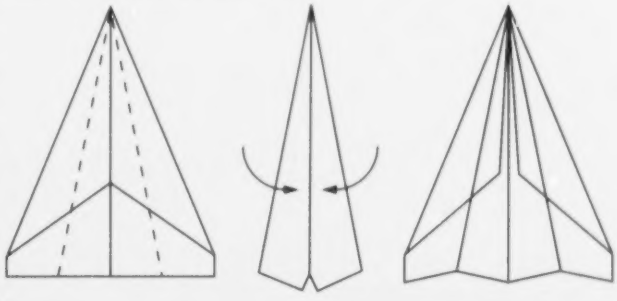
Step 1
Use a full sheet of typing paper. Using the mountain fold, fold the paper in half lengthwise. Unfold. Then valley-fold the upper corners to the center crease.



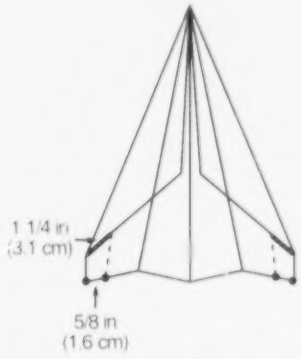
Step 2
Valley-fold along the dashed lines to form triangles that meet the center crease, as shown.

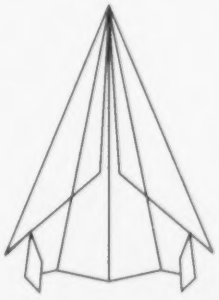


Step 3
Valley-fold the outer edges to meet the center crease as shown by the dashed lines. Unfold as shown.



Step 4
On each side, measure along the diagonal edge of the paper, as shown by the heavy line, and cut. Along the bottom edge, measure 5/8 in (1.6 cm) from each wingtip, and from this point, draw a line to the end of the cut. Valley-fold along this line to make vertical tails.



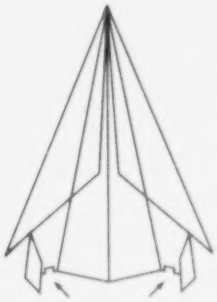


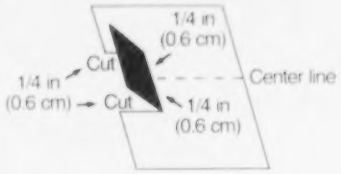
Making the Airplane

The Egret is constructed similarly to the common paper airplane that everyone makes. But because of this model's carefully measured shape, it can attain a very smooth and flat glide. Make sure that its shape is properly adjusted, with vertical tails straight up and down. Hold it between thumb and forefinger, launching it gently straight ahead.

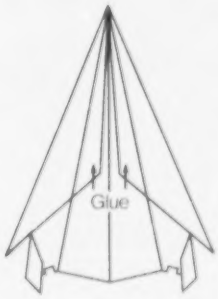
THE EGRET

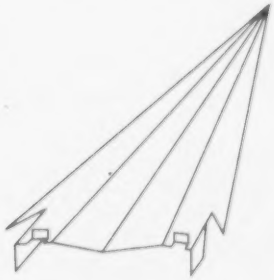
Step 5
In the locations shown, find the center line, measure, cut, and fold the elevators.

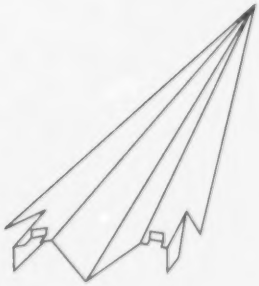




Step 6
Glue folds only at the center of the fuselage. Flip the airplane over. Adjust the shape so that when viewed from the back, the airplane makes a shallow upside-down W, as shown.







THE FLEX
EXPERT GROUP 2

Directions for Constructing the Flex

1. Find center line A of a sheet of typing paper. Valley-fold on that line and crease it. Then open the sheet.

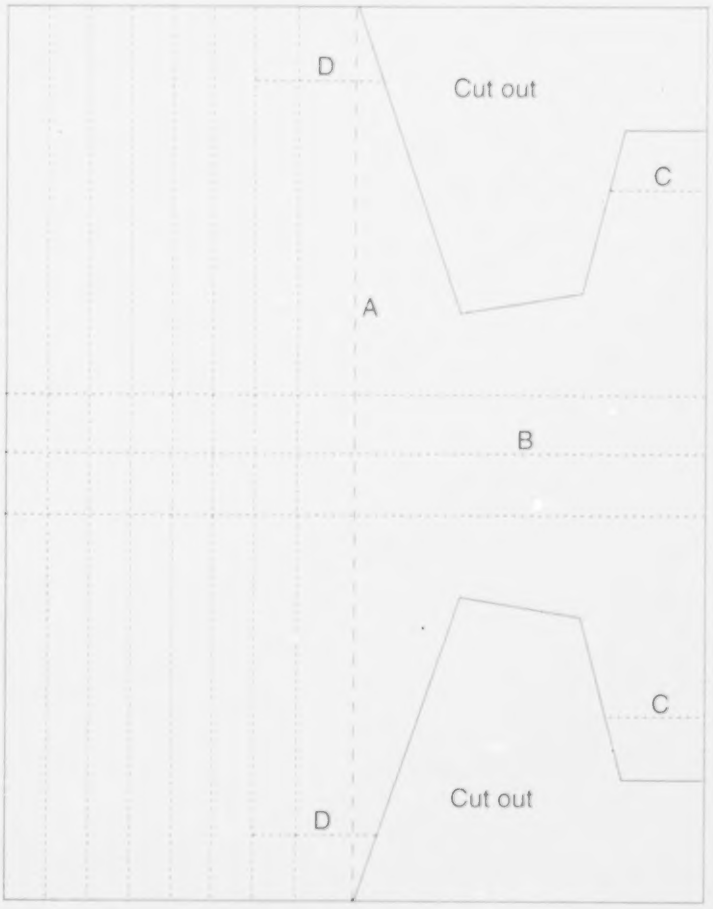
2. Mark off seven lines, each 0.5 inch apart, parallel to the left lead edge. Valley-fold and crease along each line, "rolling" the paper flat toward the tail end.

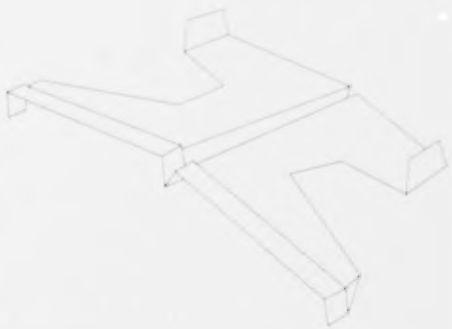
3. Valley-fold on center line B. Cut out the wings and tail section of the plane as shown on the pattern.

4. Mountain-fold on both sides of line B about 0.5 inch from line B to form the body of the plane.

5. Valley-fold to form the tail flaps and mountain-fold to form the wing flaps as indicated by dashed lines C and D on the pattern.

By changing the positions of the wing and tail flaps, students can make this plane perform many different maneuvers.





THE BASIC SQUARE
EXPERT GROUP 3

Directions for Constructing the Basic Square

1. Use a full sheet of typing paper (see fig. 1).

2. Begin to make parallel valley folds, starting at the bottom of the sheet (see fig. 2).

3. Continue until the "wing" areas are just about square (see fig. 3).

4. Valley-fold along the center line (see fig. 4).

5. Mountain-fold the two wings parallel to the center line, leaving about 0.5 inch on either side of the line for the body of the plane (see figs. 5 and 6).

6. Be sure to crease the folds nicely at the front of the plane.

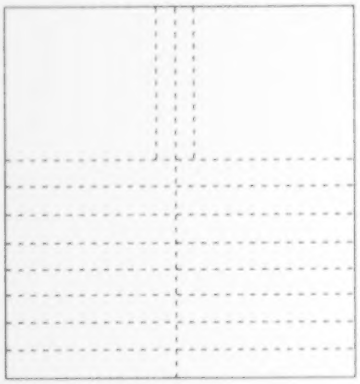


Figure 1

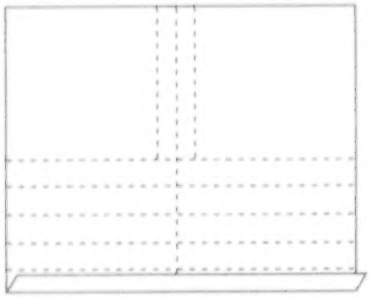


Figure 2

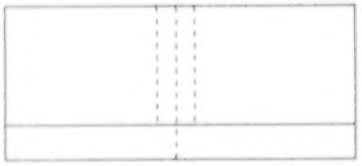


Figure 3

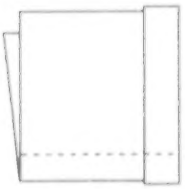


Figure 4

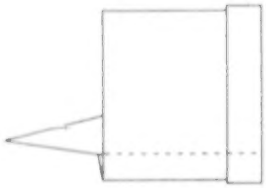


Figure 5

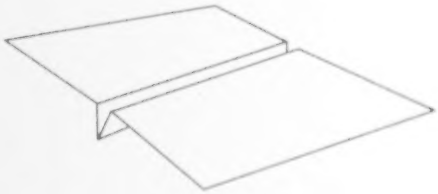


Figure 6

7. To fly well, your plane should have its wings higher than the body so as to form a Y shape (see fig. 7).

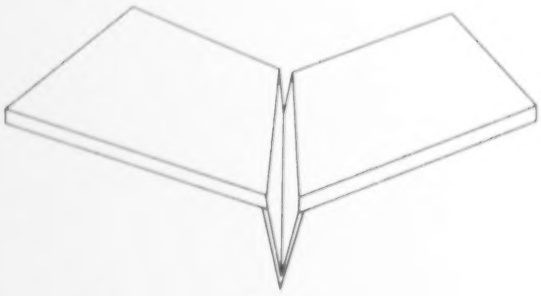


Figure 7

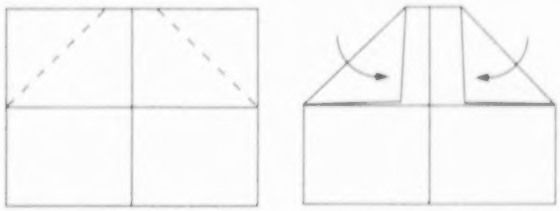
This plane is modeled after the "Basic Square," described by Ken Blackburn in *The World Record Paper Airplane Book* (1994). Ken is the world-record holder for keeping a paper airplane aloft (18.80 seconds).

THE CONDOR
EXPERT GROUP 4

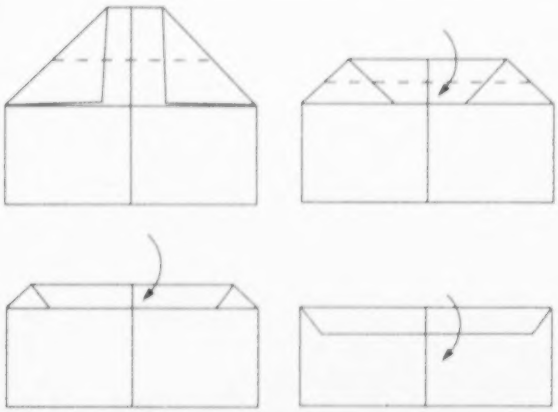
Directions for Constructing the Condor

Step 1
Use a full sheet of typing paper. Mountain-fold the paper in half lengthwise. Unfold. Then valley-fold it in half perpendicular to the first fold. Unfold.

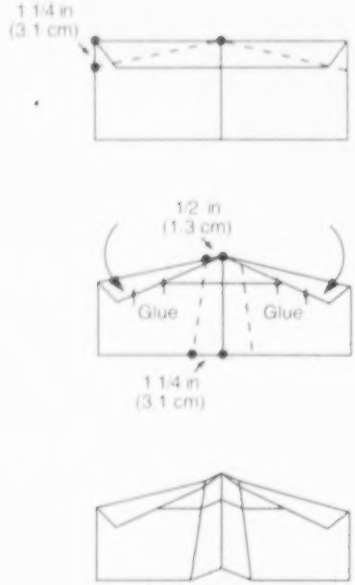
Step 2
On each side, valley-fold the top corners diagonally so that the outer edges meet the horizontal crease.



Step 3
Make a valley fold parallel to the step-1 lengthwise crease so that the top edge meets the crease. Make another valley fold so that the top edge meets the crease. Then refold the original lengthwise crease.



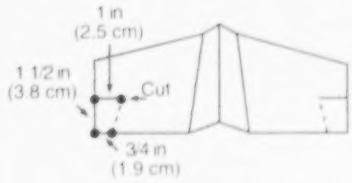
Step 4
On each side of the step-1 perpendicular crease, measure and draw diagonal lines as shown. Valley-fold the top outer edges along these lines. Glue the folded-over triangles to form the leading (front) edges of the wings. Then measure and draw lines as shown. Valley-fold along these lines to form the fuselage.



Making the Airplane
Condors have large feathers at their wingtips for control. Instead of feathers, this airplane has winglets. Because of its wide wing span, this paper airplane is fragile where the wings meet the fuselage. Adjust the winglets and bend the airplane to adjust the trim.

THE CONDOR

Step 5
Flip the plane over. On each side, measure and draw the lines for the winglets as shown. Cut on the heavy lines. Valley-fold as indicated to make the winglets. Make the canopy.



Canopy

Step 6
Apply glue to the inside of the nose only, and insert the canopy. Align it with the nose. Adjust the shape so that the wings have a slight dihedral angle (upward slant)

View from back

and the winglets slant upward, as shown.

Making the Canopy

1. Measure and cut a 2" X 3" (5 cm × 7.5 cm) rectangle from paper. Lay the paper flat. Use a mountain fold to fold it in half lengthwise.

2. Measure the top point as shown, and draw diagonal lines to the corners. Then, with the paper folded in half as in step 1, sink-fold the corners. A sink fold changes part of a mountain fold into a valley fold.

3. Press the canopy flat to finish it.

TEST-FLIGHT DATA SHEET

Date: _____

Mission Specialist's Name: _____

Team Name: _____

Members: _____

_____

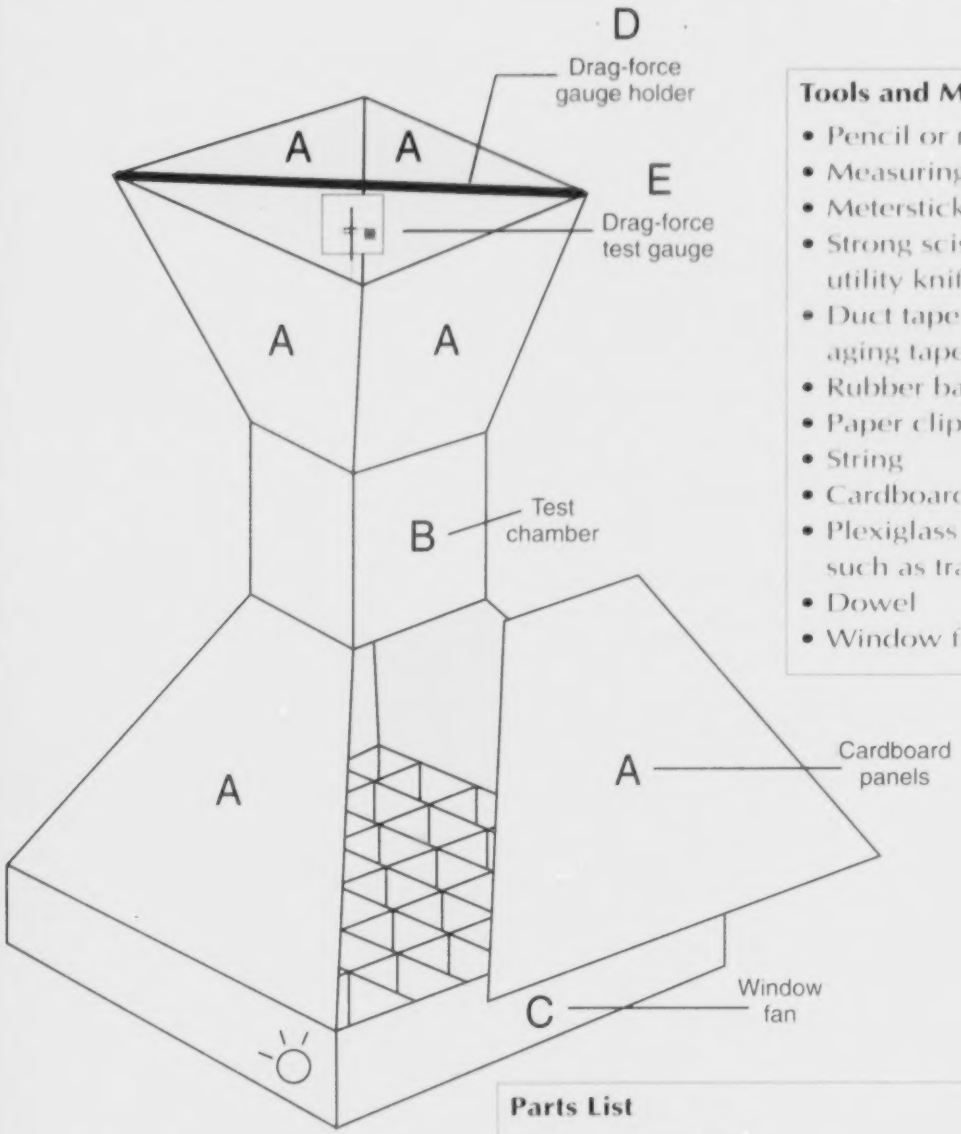
_____

_____

_____

Line Plots for Distance Trials:

INSTRUCTIONS FOR ASSEMBLING THE WIND TUNNEL



Tools and Materials:

- Pencil or marker
- Measuring tapes or rulers
- Meterstick
- Strong scissors or utility knife
- Duct tape or clear packaging tape, 2″ wide
- Rubber band
- Paper clip
- String
- Cardboard
- Plexiglass or plastic, such as transparency film
- Dowel
- Window fan

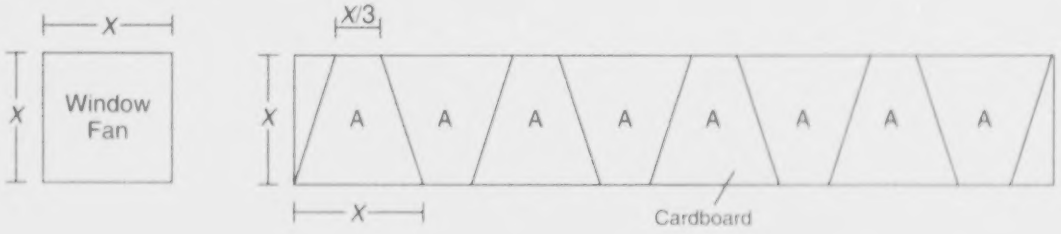
Parts List

Part	*Description*	*Material*
A	Funnel sides	Cardboard
B	Test chamber	Plexiglass*
C	Window fan	
D	Drag-force gauge holder	Dowel
E	Drag-force test gauge	Cardboard
		Rubber band
		Paper clip

* Cardboard can be substituted for three sides. At least one side must be transparent.

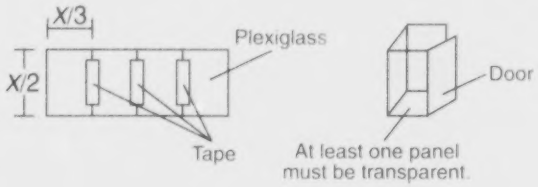
Engineering Team 1

Measure, cut, and tape the cardboard for all wind-tunnel sections (part A). The plans below indicate the dimensions of these trapezoid-shaped panels, based on the size of your window fan (*X*).



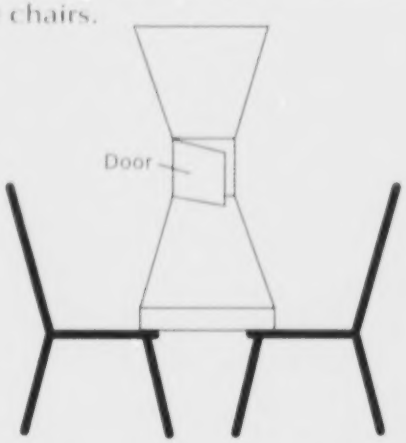
Engineering Team 2

Measure, cut, and tape the material for the test-chamber section (part B). The plans below indicate the dimensions of these panels, based on the size of your window fan (*X*).



Engineering Team 3

Assemble and tape the chair supports for the window fan, which will be the base for the wind tunnel. Position the fan so that it draws air out of the wind tunnel. The door should not open toward either of the chairs.



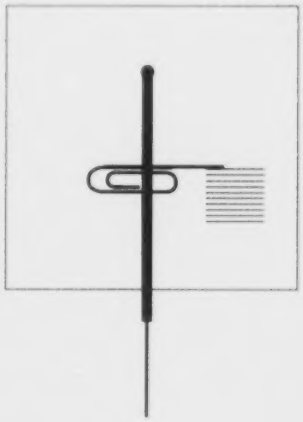
Engineering Team 4

Build the drag-force test gauge (parts D and E). See the diagram below.

The gauge starts with a 5″ × 5″ card. Poke a hole 1″ down from the center of the top edge. Put a standard office rubber band through the hole and tie a knot on the back of the card.

Mark calibration lines 1/16″ apart.

Bend a small paper clip and attach it to the rubber band. It should touch the top mark.

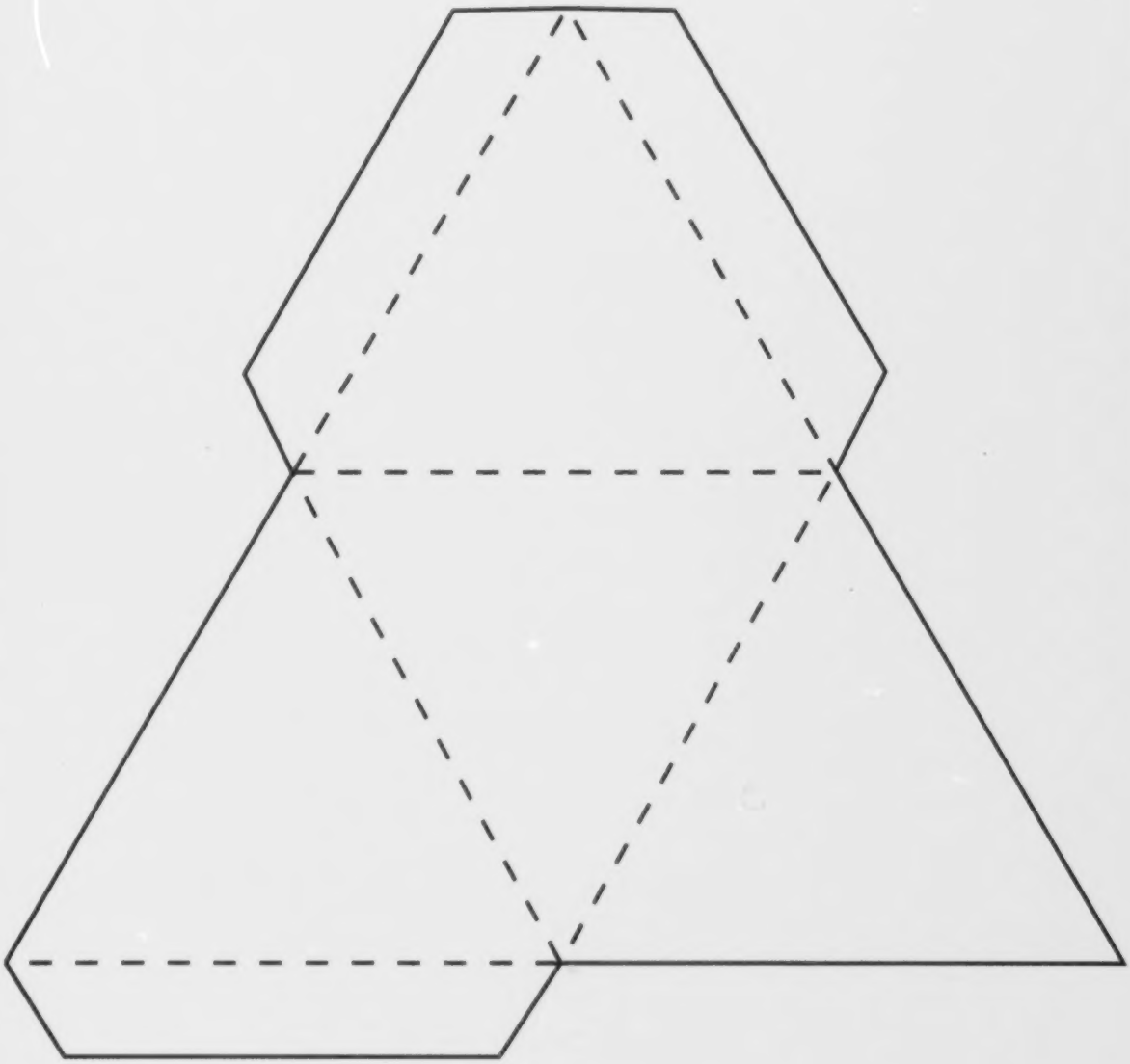


Tie a string to the free end of the rubber band. The string must reach down to the test chamber of the wind tunnel.

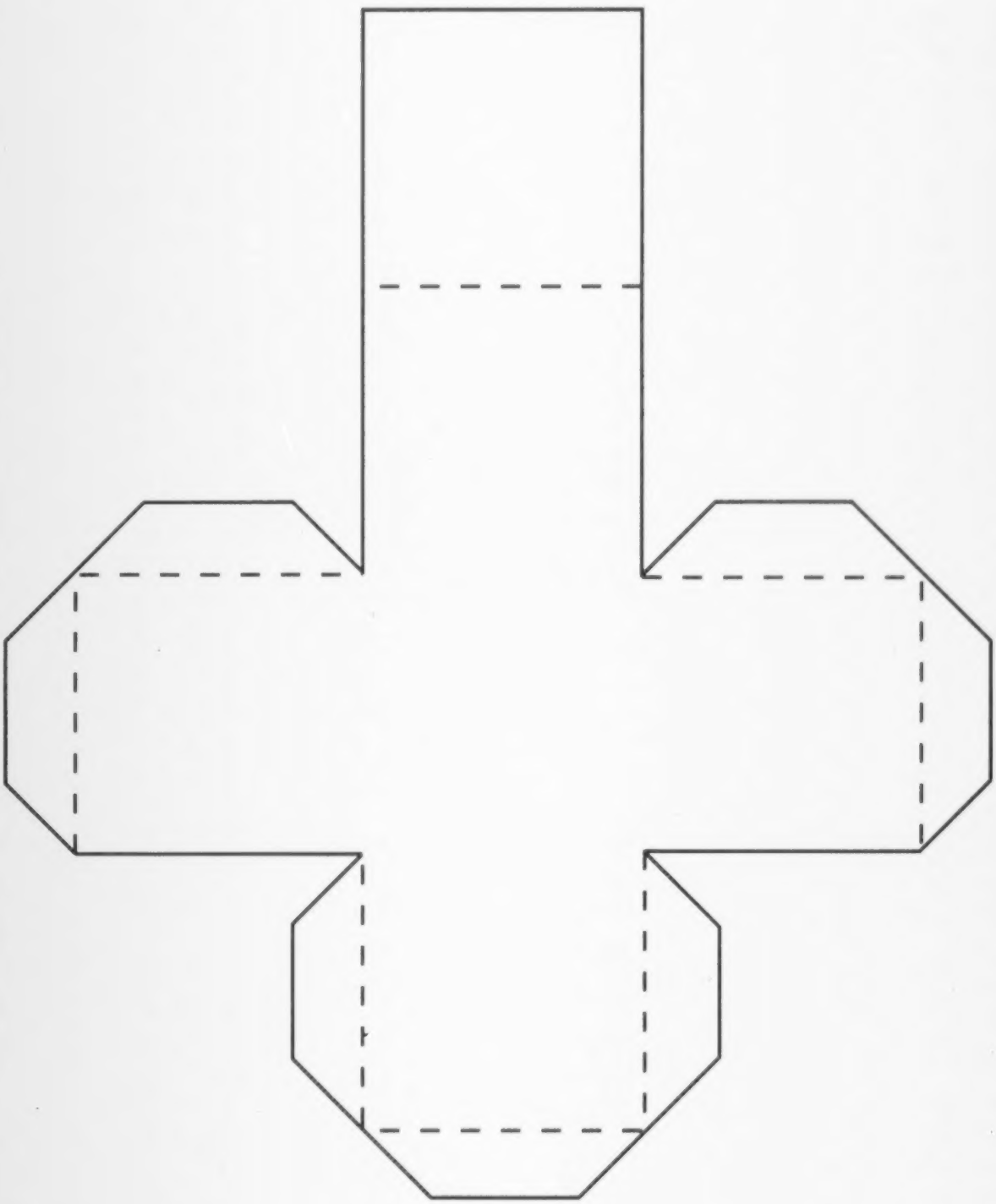
Engineering Team 5

Using the nets on the following pages, build from cardboard the following polyhedra: a cube, a pyramid, and a cone. Use tape to attach a string to each of these solids.

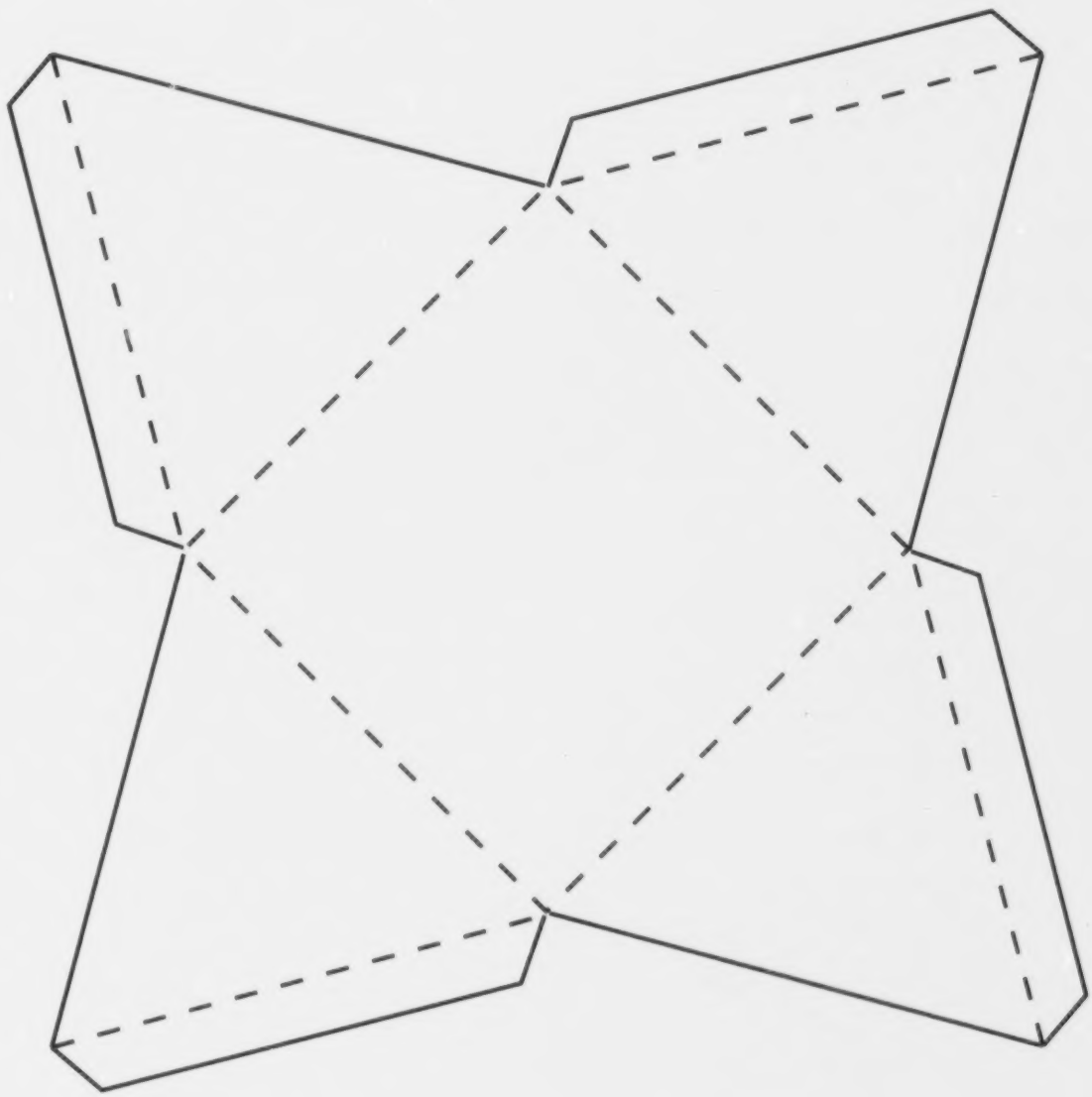
NET FOR A TETRAHEDRON



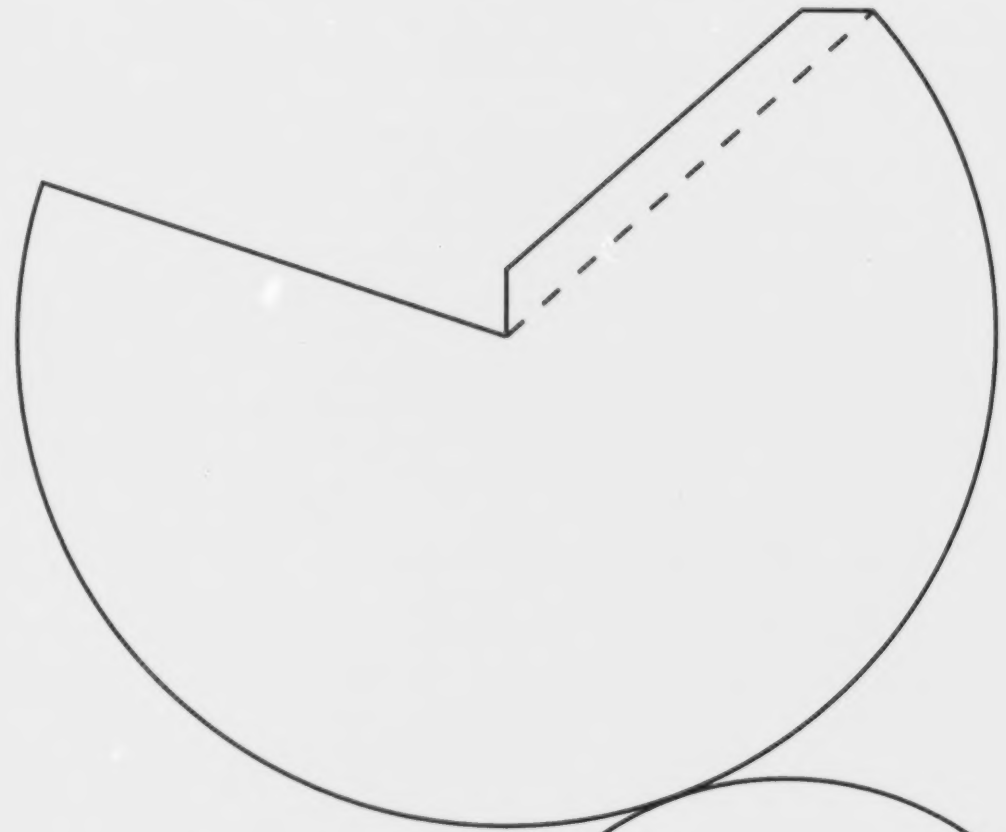
NET FOR A CUBE

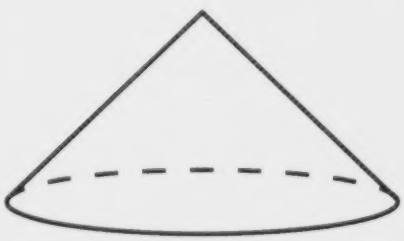


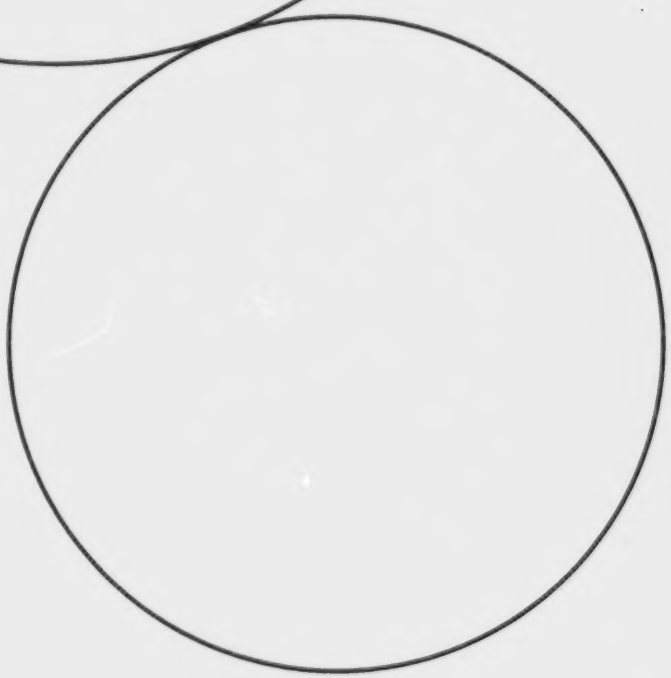
NET FOR A PYRAMID



NET FOR A CONE







EVENT SPECIFICATIONS FORM

Air Olympics
Event Specifications Form

Event Title:

Expert Team Members:

Describe the event in words:

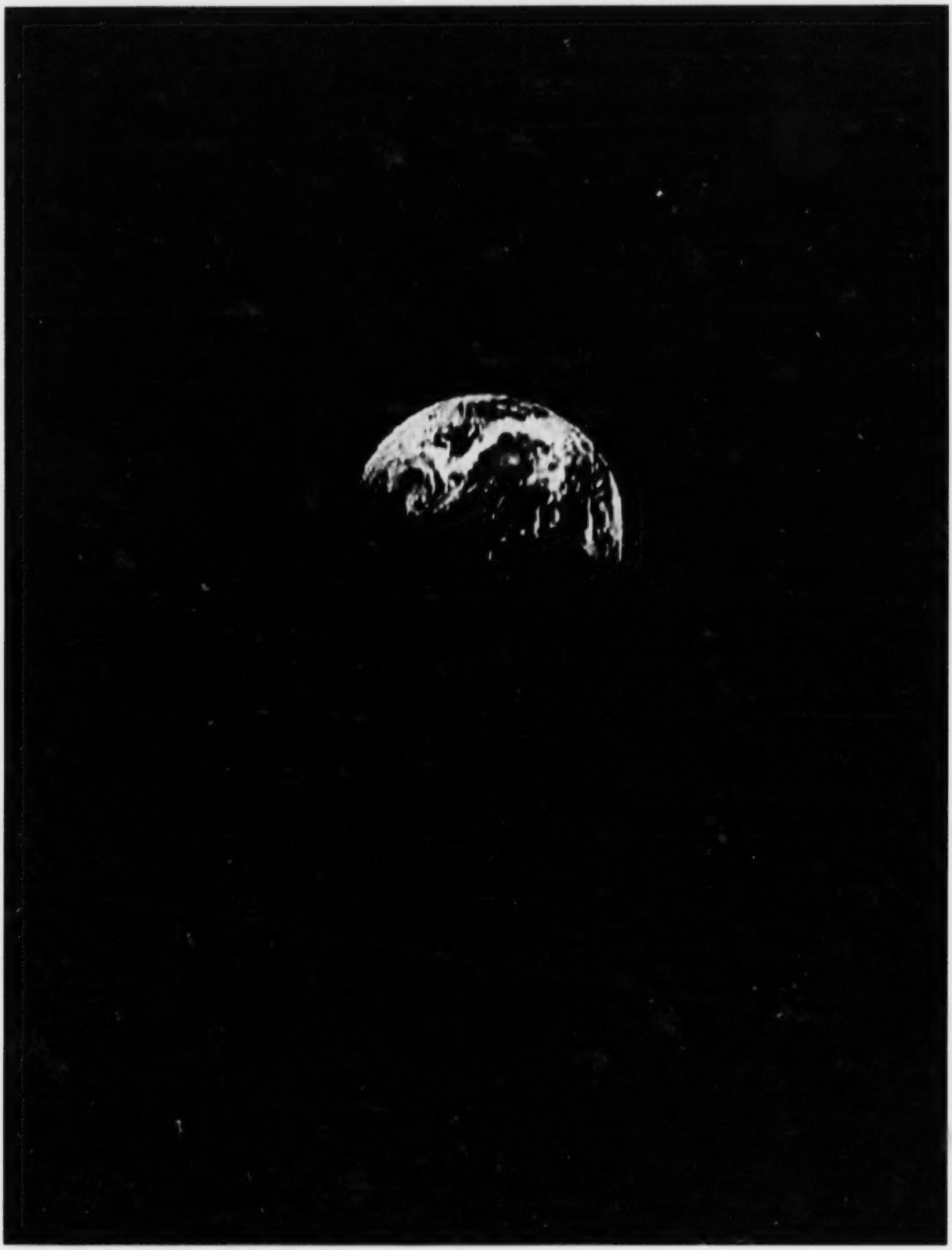
Describe the rules for the event:

Describe the judges who will be needed at this event and tell about their duties:

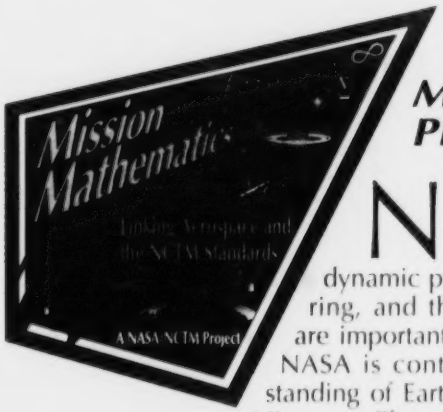
Describe the equipment that will be needed for this event:

Provide a scale drawing of the area needed for this event. Be sure to indicate the location of an area from which participants can safely watch, and also indicate the locations of the judge(s):

Describe the event in words:

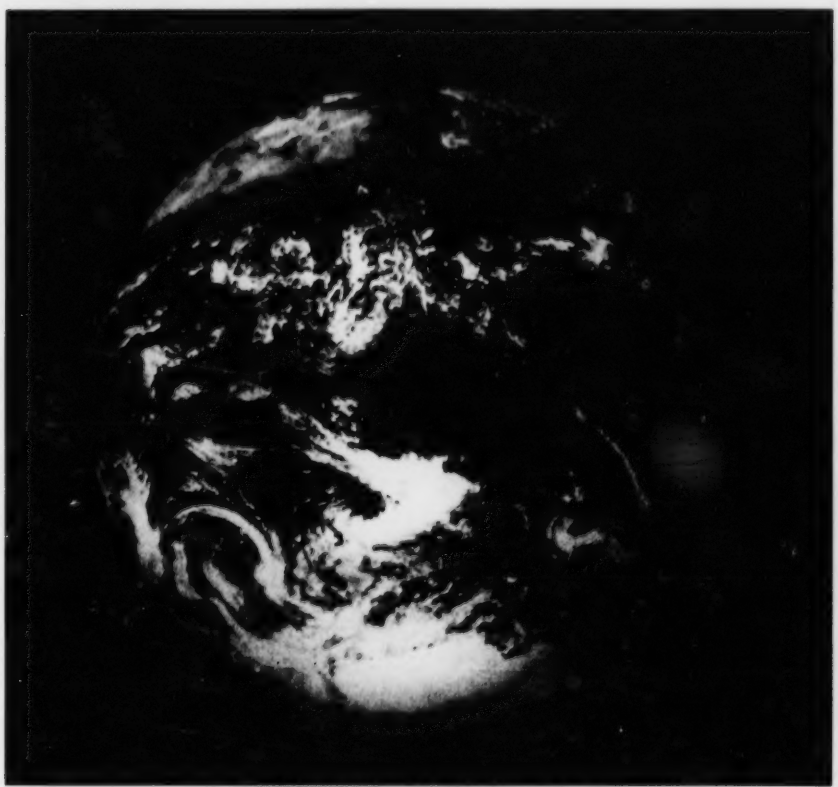


BEST COPY AVAILABLE



MISSION TO PLANET EARTH

NASA is playing an integral role in the effort to understand the complexities of our planet. Earth is a dynamic planet. Change is constantly occurring, and the consequences of the changes are important to the future of the human race. NASA is contributing to humankind's understanding of Earth through the program known as Misson to Planet Earth (MTPE). Since 1991 NASA has been providing support to scientific research that focuses on specific aspects of Earth's environment. These efforts have often been conducted in cooperation with other federal agencies and scientists from other nations.



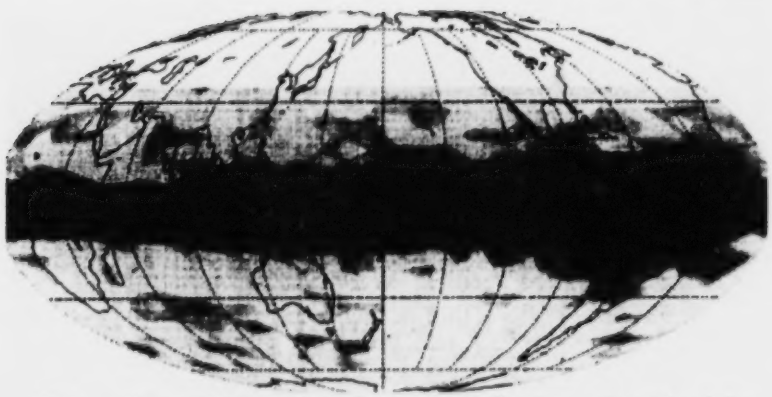
A photograph of Earth from space

The goals of MTPE are the following (NASA 1994, p. 24):

- to understand Earth as an integrated system;
- to gain comprehensive knowledge of the interactions among the planet's mechanisms;
- to learn exactly how the planet is changing and the extent to which human activities are contributing to change;
- to assess the potential consequences of change; and
- to provide the knowledge base for sound policy decisions about the future of Earth's environment.

Phase 1 of MTPE has been under way since 1991. This phase involves data gathering by NASA satellites, by NASA instruments aboard the satellites of other U.S. agencies and other countries, by Space Shuttle–based instruments, by instruments on airplanes as well as balloons, and by ground-based instruments (NASA 1993, p. 28). The table below highlights some of the efforts to collect data from our planet.

Mission	Instruments	Results
Ozone monitoring	Total Ozone Mapping Spectrometer (TOMS) and Shuttle Solar Backscatter Ultraviolet (SSBUV)	International agreements to phase out the use of chlorofluorocarbons
Study of volcanic ash	Earth Radiation Budget Satellite (ERBS)	Increased knowledge of the effect of volcanic eruptions on global temperature
Study of ocean topography	U.S.-France Ocean Topography Experiment (TOPEX/Poseidon)	The first map of the ocean floor and a study of the weather phenomenon El Niño
Study of tectonic plate movement	U.S.-Italy satellite program known as LAGEOS II	A data bank on the movement of tectonic plates that helps scientists understand earthquakes



The eruption of Mount Pinatubo in the Philippines released sulphur dioxide, which appears in this 1991 diagram as a dark belt concentrated around the tropics.

Phase 1 of MTPE has been characterized by a focus on specific aspects of the global environment, whereas phase 2 will focus on the long-term interactions among components of Earth's system. Phase 2 involves the launch of a series of Earth Observing Spacecraft (EOS). EOS will involve flights of a diverse set of instruments on a number of spacecraft over a 15-year period. Scientists using advanced computing systems will compile the data about Earth from all available data and attempt to model Earth as a global system. Particular attention will be paid to how human activities affect the planet (NASA 1993, p. 23).

LESSON 1
POLAR ICE

Mission

To suggest some attributes of the polar ice cap that would be important to measure

To devise and use various approximation techniques to estimate the area of a figure that represents a polar ice cap

NCTM Mathematics Standards

Measurement

Estimation

Statistics

Sea levels have been rising slowly for nearly a century. Part of this change can be attributed to the melting of some glaciers and ice caps around the world. What we don't know is whether the world's two major ice sheets—in Greenland and Antarctica—are growing or melting. This is important to know because these areas are so large that their behavior can have global effects. As a point of reference, these two ice sheets contain approximately 75 percent of Earth's fresh water in frozen form. If they melted entirely, it is estimated that sea levels would rise approximately 75 meters. This rise would flood much of the United States. Coastal states such as Florida would be nearly covered by such a phenomenon. Although dramatic changes in the amount of ice in the glaciers, ice caps, and ice sheets of the world are not likely to occur in a short time, it is important that scientists monitor the extent of these frozen bodies. Subtle changes in any of them may be a signal that a long-term trend toward global warming or cooling is occurring.

NASA has been collecting data about ice masses for some time now. Early satellites in the 1960s and 1970s obtained valuable information, but the sophistication and power of the instruments on those early missions do not match those of the instruments available today. The main initiative of NASA's Mission to Planet Earth, the Earth Observing System (EOS), will have instruments that are capable of collecting more-sophisticated ice data even when clouds obscure the ice sheets from view. The series of EOS satellites will collect data over a period of 15 to 20 years. This information will allow scientists to determine trends in data that indicate global warming or cooling.

Teaching Note: ***Some natural phenomena and resources of Antarctica that may interest students include the following:***

penguins

whales

seals

fossils

the size of the ice mass

temperature ranges

the amount of snowfall

ozone depletion

petroleum and gas supplies

PURPOSE

By looking at classroom globes, maps in books, and NASA images, students realize the extent of ice in the world. They also see that the areas covered by ice are irregularly shaped. Students think about the attributes of polar ice that are important for scientists to monitor. The focus of the activity for all students is determining the area of an ice mass. Multiple approaches to finding the area of an irregular figure are considered.

GETTING STARTED

Introduce the lesson by discussing explorers and scientists associated with the North Pole or Antarctica. Talk about those adventurous people who have trekked across snow and ice to reach the North Pole or about scientists who have been living in Antarctica to study the natural phenomena and resources of the area.

Show some maps or pictures of the polar ice caps. Globes and maps will allow students some notion of the relative sizes of the ice caps. Photographs from NASA Landsat satellites show the Arctic and Antarctic regions in a dramatic way. These images can be used to initiate a discussion of what is important to observe (measure) about the ice masses.

Muir Glacier, Glacier Bay, Alaska (1971)

BEST COPY AVAILABLE

A Sample Class List of the Attributes of Ice Sheets

length	*volume*
width	*temperature*
radius	*acidity*
depth	*weight*
perimeter	*composition*
area	

Allow the students to brainstorm in small groups ideas about what scientists would want to know about ice that occurs in nature in such large quantities. After the brainstorming session, allow the groups to share one or two ideas each. Make a class list of the attributes of ice masses that would be important to scientists.

Lead a discussion about which attributes on the list could be measured by using instruments on satellites. Students' knowledge of sensing instrumentation will vary. All ideas should be accepted. However, most students will know that photographs are taken from satellites and that these images could be compared over time. Comparisons of pictures from the same seasons of the year can show whether there are perceptible differences in the area of the ice caps.

Materials: ***A resource page for each student, graph paper, rulers, maps or photographs of the polar ice caps, and a globe***

DEVELOPING THE ACTIVITY

Focus the discussion on measuring the area of an ice mass. The students will need to consider how to measure the area of irregular figures. Have them return to their groups and brainstorm ideas for doing so. Once a group reports that they have devised a method for approximating the area of irregular figures, give them copies of the figure on page 126 to try their technique by determining the area of the ice mass represented by the scaled figure.

After the groups have used their technique to approximate the area of the ice mass represented by the irregular figure on page 126, have them share their procedures and answers with the entire class. The students should be encouraged to try the methods shared by other groups.

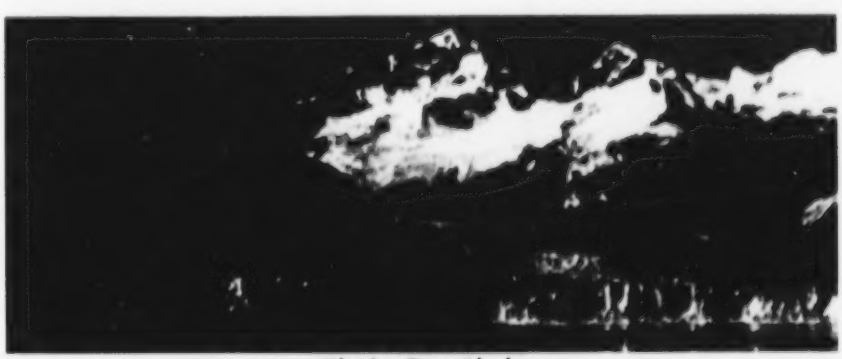
The students should try the following three techniques if they have not already been proposed:

Teaching Note: ***For the first method of approximating the area, copy page 126 and have the students lay the page on top of a piece of graph paper. They should be able to see the graph-paper squares through the copy.***

1. Use graph paper to facilitate the counting of squares inside the area. Of course, the issue of partial squares is always a topic of conversation. Let the students use their knowledge of fractions to estimate the area of each partial piece. These areas can be added by using paper-and-pencil algorithms or a fraction calculator.

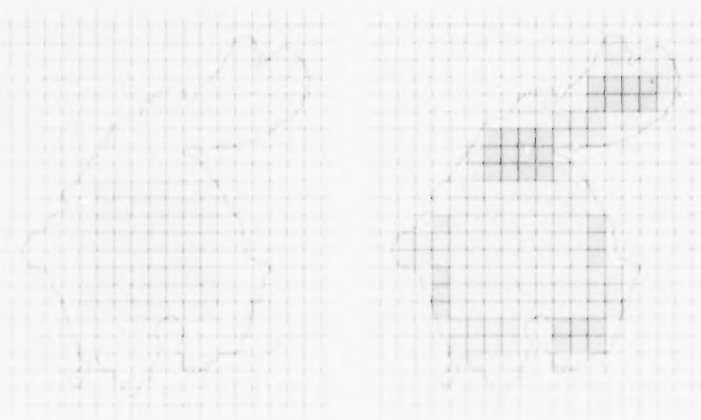
   Another method for estimating the area of partial squares is to count each of them as a half regardless of its size. Have the students do this and compare the results to the approximations made by using more "precise" fractions.

Teaching Note: ***Two methods of estimating the area of the partial squares are suggested. After the two methods are used by the students, have them discuss which method would be best to use with and which without a calculator. The "one-half method" is easily accomplished mentally by counting the partial squares and "taking one-half of them." Estimating more precisely requires adding fractions, a method more suited to using fraction calculators. Making decisions about when to use technology is an important part of mathematics today.***

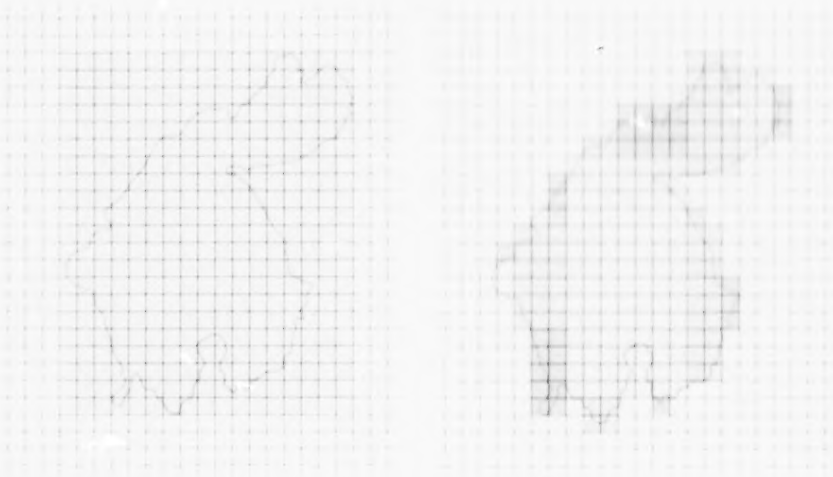


Glacier Bay, Alaska

2. Draw the largest possible rectangle inside the irregular area. This rectangle should not lie outside any portion of the figure. The students should record the area of this rectangle. Next, have them draw two rectangles inside another copy of the figure that fill more of it than the single rectangle did. Compute the areas and the sum of the two as an approximation of the area. Repeat the process with three, four, five, and perhaps six rectangles. As the students compute the sums of these rectangular areas, they should see that the approximation gets closer to the actual area with each increase in the number of rectangles. Let the students continue the process until they tire of the task and think they have a reasonable approximation of the area.



3. Use a similar process with external rectangles, and approach the area from an approximation that is greater than the actual area. Draw a large rectangle around the irregular figure that is tangent to it in at least three places. Compute the area. Repeat the process with two smaller rectangles on another copy of the figure. This time one shared side of each rectangle will pass through the figure so that each rectangle encloses part of the figure. The entire figure should be inside the two rectangles. Then repeat the process with an increasing number of rectangles until the students can see the approximation approaching the value of the actual area.



CLOSING THE ACTIVITY

The students have had several experiences with approximating the area of an irregular figure. Have them write in their mission log books about their experiences. Tell them to ask questions about any ideas they did not understand and to specify topics they would like to study again or in more depth. Encourage them to think about the methods of approximation and describe one as if they were explaining the method to a friend.

Also, have them reflect on how NASA scientists might use these same approximation techniques to determine the area of an ice region.

LESSON 2
ORBITING SATELLITES

NCTM Mathematics Standards

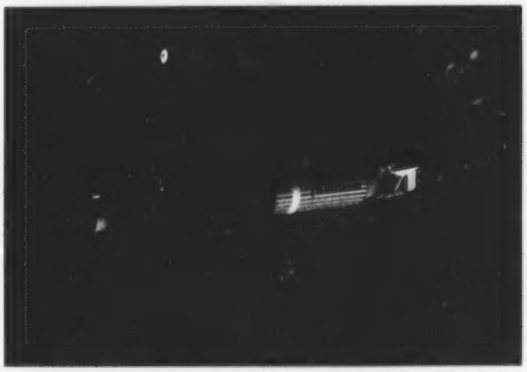
Geometry

Algebra

Mission

To use algebraic thinking to determine facts about orbiting satellites

Weather satellites are important for collecting data about Earth. These unmanned spacecraft carry a variety of sensory equipment that scans Earth and electronically communicates the data back to scientists on Earth. Two types of environmental satellite systems named for their orbital characteristics, geostationary and polar-orbiting satellites, provide the data for scientists to study our environment.



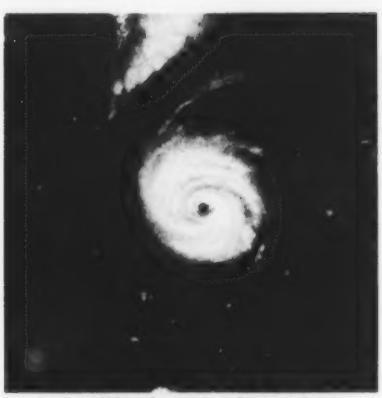
Seasat *was the first Earth-orbiting satellite designed for remote sensing of Earth's oceans.*

Geostationary satellites orbit at a speed that enables them to remain constantly over the same area of Earth. This position provides constant "viewing" of a specific area of Earth. The Geostationary Operational Environmental Satellites are an important system for the United States. These satellites are maneuvered into orbits that ensure constant coverage of the Western Hemisphere. They continually produce infrared images, weather charts, ice charts, and other data important to the study of the environment.

Polar-orbiting satellites operate in orbits that cause them to pass almost over the poles of Earth. Many of these satellites operate in Sun-synchronous orbits. These Sun-synchronous orbits are designed so that the satellite passes over the same terrain at the same time each day. This orbital feature is important for the collection of data about Earth.

PURPOSE

In this lesson students explore the concept of orbits. The connection of Earth-orbiting satellites to the study of the environment is used to interest students in this lesson. Both geometric and algebraic concepts are presented to students in this science context.



A satellite image of Hurricane Fran off the east coast of Florida

GETTING STARTED

Engage the class in a large-group discussion about the satellite images they see on local television news broadcasts. In the discussion, help the students distinguish among animations of Shuttle missions, photographs from the Space Shuttle, pictures from remote robotic explorations such as Pathfinder on Mars, Hubble Space Telescope images, and satellite photographs of Earth. If possible, obtain a videotape of a television weather report of a fast-moving storm that has been tracked and shown in nearly real time. If the videotape cannot be obtained, just ask students to recall watching such events on television. As part of the discussion, ask students to speculate on how the television station obtained these images. Some students may know that some TV weather graphics are made with satellite data.

This discussion can lead to an opportunity to present the notions of geostationary and polar-orbiting satellites. The notion of polar-orbiting satellites—those whose orbits take them above both poles—may be easier for students to understand. They seem to understand the notion of the ground track of polar-orbiting satellites. The reason may be that the movement of these satellites is similar to that of an airplane in the sky. Thus, presenting the polar-orbiting notion first may be desirable. The class discussion will determine if this seems appropriate.

A polar-orbiting satellite

Part A

DEVELOPING THE ACTIVITY

Question: How do you determine the velocity of a polar-orbiting satellite when the altitude and the period of the orbit are known? For example, if a 750-mile-high satellite orbits Earth every 3 hours, 45 minutes, how fast is it traveling? That is, what is the velocity of the satellite?

Allow the students to work in small groups to draw pictures of the situation and attempt to think through the solution to the problem without doing the actual computation. Encourage them to write statements such as "I would first change the 3 hours, 45 minutes to hours in decimal form." Another statement might be "I would compute the distance that the satellite travels in one orbit of Earth by using the formula for the circumference of a circle."

Teaching Note: ***To simplify the notion of orbits for middle school students, the orbits discussed in these activities are assumed to be circular.***

Once the group has a plan to compute the velocity of the satellite, have each student in the group do the calculations to determine the velocity.

Definition: ***The orbital period is the time required to complete one orbit around Earth.***

Sample solution path for the example

Step 1. Change 3 hours, 45 minutes to

$$3\frac{45}{60} \text{ hours} = 3\frac{9}{12} \text{ hours}$$

$$= 3\frac{3}{4} \text{ hours}$$

$$= 3.75 \text{ hours.}$$

Teaching Note: ***For computations in this book, we use 3.14 as the value of*** π.

Note that a fraction calculator can be used in this instance.

The radius of an orbit is calculated from the center of Earth. Consequently, the radius of an orbit equals the radius of Earth plus the altitude of the satellite above Earth.

Step 2. According to the formula $C = 2 \times \pi \times r$, the distance traveled is

$$2 \times \pi \times (3\,960.5 + 750) \text{ miles} = 29\,581 \text{ miles.}$$

Step 3. This distance is traveled each 3.75 hours. Therefore, the speed, or velocity, of the satellite is

$$\frac{29\,581 \text{ miles}}{3.75 \text{ hours}} = 7\,888 \text{ miles per hour.}$$

The mean distance for the radius of Earth is 3 960.5 miles. Since Earth does not have a smooth surface, the radius varies slightly from one point to another. If it seems instructionally appropriate, an approximation, such as 4 000 miles, can be substituted.

Additional Exercises

Altitude above Earth	Period	Velocity
170 miles	1.5 hours	*~17 293 mph*
20 150 miles	20 hours	*~7 570 mph*

CLOSING THE ACTIVITY

When the students are sharing solutions, emphasize the path to the solution. Talk about the different approaches the students used to reach the same solution. Later in a more formal algebra class, a teacher may focus on the equivalent forms of equations used to solve the problem.

Part B

DEVELOPING THE ACTIVITY

Related Mission Mathematics Activity: ***The activities in the Mission Mathematics: Grades 9–12 poster "Locating Satellites in Elliptical Orbits" are good references for teachers.***

Question: How do you find the altitude of a geosynchronous satellite that is orbiting Earth above the equator? The velocity of the satellite must be known. Using a value for the velocity, we could ask, "If there is a satellite traveling at 6 900 miles per hour, how high must it be orbiting?"

This question is sometimes difficult for students because there is only one number in the problem. Putting students into groups to draw pictures and think about what is known about the problem will usually help them identify all the pertinent data. Drawing pictures will help their discussions.

Teaching Note: ***A satellite that orbits Earth every 24 hours is said to be in a geosynchronous orbit. If a satellite is in geosynchronous orbit along the equatorial plane, it is geostationary as well. That is, it will remain at the same point above Earth's surface as it orbits the planet.***

One possible solution path

Step 1. A geostationary satellite "orbits" Earth once every 24 hours. The time of the orbit is what makes it appear not to move. It is moving in unison with Earth's rotation.

Step 2. If a satellite travels 6 900 miles in 1 hour, how far does it travel in the 1-day orbit (a period of 1 day)?

$$6\,900 \text{ miles per hour} \times 24 \text{ hours} = 165\,600 \text{ miles}$$

Step 3. 165 600 miles is the circumference of a circle. $C = 2 \times \pi \times r$.
So $2 \times \pi \times r = 165\,600$, or

$$\pi \times r = \frac{165\,600}{2}$$

$$= 82\,800 \text{ miles},$$

and

$$r = \frac{82\,800}{\pi}$$

$$= 26\,369 \text{ miles}.$$

Step 4. 26 369 miles is the radius of a circle whose center is the center of Earth. To determine the satellite's altitude above the surface of Earth, the radius of Earth (3 960.5 miles) must be subtracted from the radius of the circle. The altitude becomes $26\,369 - 3\,960.5 = 22\,408.5$ miles above Earth.

CLOSING THE ACTIVITY

Once again, it is important to have the students share their solutions to this problem. They may see different paths to the same solution. When students share their thinking, some of their classmates will gain new or heightened understanding of the lesson topics.

CLOSING THE LESSON

Geostationary satellites stay above the same point on Earth regardless of the time of day.

Have the students record their new understanding of both the science and the mathematics of orbiting satellites on their mission log sheets.

LESSON 3
TRACKING MIGRATING WHALES

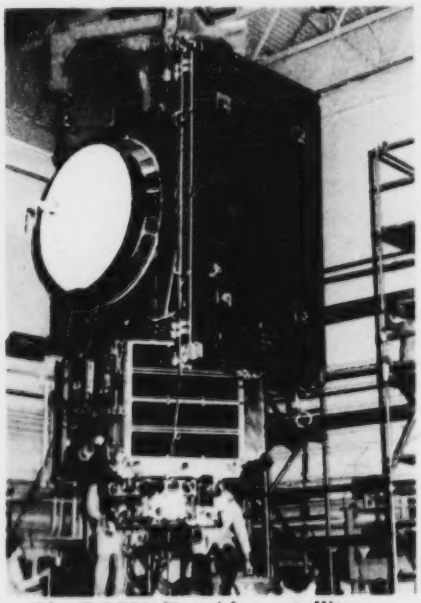
Mission

To make accurate measurements with a ruler or yardstick
To determine distances by using ratios from scaled maps
To use the Pythagorean theorem to determine distances
To read a compass and use compass directions

NCTM Mathematics Standards

Measurement

Algebra



The TOPEX/Poseidon satellite before its launch in September 1992

For many years scientists and environmentalists have been concerned about the number of whales remaining in the world. This concern continues today. Scientists are studying many species of whales to determine, among many things, whether the population of each of the whale species is increasing or decreasing. The use of satellites and radio transmitters attached to selected animals aids scientists in tracking them. Thus the habits of whales, including migration, can be determined and scientists can monitor the population dynamics of the mammals.

Making Connections: ***This lesson has natural connections to both science and social studies. Some ideas about whales are clearly a part of the science curriculum, and the migration of whales adds a focus on concepts from geography.***

This lesson uses the interdisciplinary nature of the study of whales to apply several mathematical ideas. It allows the application of technology in the form of calculators. Also, the introduction of the newer technology of Global Positioning Systems (GPS) is possible with this lesson. GPS hand-held units are now available in most stores where hunting and fishing gear is sold. The fishing industry uses GPS units to mark locations where fish are found to be plentiful. Hunters and hikers use these same units to locate hunting sites and to find their way from a wilderness location back to a base camp. There is a great deal of mathematics to be learned from exploring the use of GPS. *Mission Mathematics: Grades 9–12* discusses the mathematics underlying GPS. Also, one of the *Mission Mathematics: Grades 9–12* posters outlines the basic features and common uses of GPS. (Specific references to these writings appear later in the lesson.)

A humpback whale

PURPOSE

This lesson provides students experience with real-world applications of mathematics from the middle school curriculum. Technology is available that allows people to use mathematics in many settings. This lesson involves the use of calculators and, if available, GPS units to explore mathematical ideas associated with distances and locations on Earth.

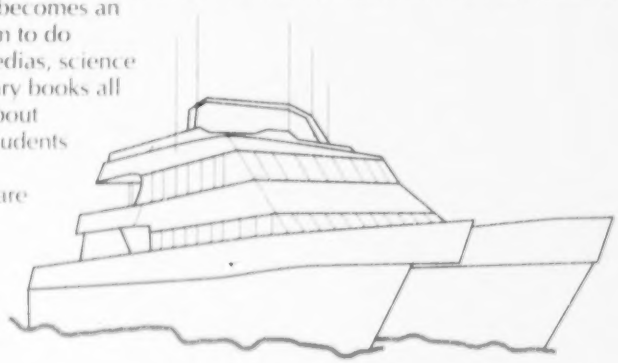
BEST COPY AVAILABLE

Part A

GETTING STARTED

Teaching Tip: ***This lesson is based on the migration of humpback whales on the East Coast of the United States. For students who live nearer the Pacific Ocean, the gray whale may be a more appropriate animal to use for motivation. With a minimum of research, information about gray whales can be found in school libraries. Important data for teachers to have for the lesson are the range of migration and some names of geographic locations at each end of the range. Students will add most of the other interesting data for the lesson from their research.***

Many students have some knowledge of whales. Begin this lesson with a discussion of what the class knows about these large aquatic mammals. Record all the information offered by students on chart paper, the chalkboard, or a blank transparency. Since this lesson will focus on the migration of whales, it is important that students indicate some knowledge of migratory behavior. If the students do not seem to have much prior knowledge of whales, particularly the migration of whales, this lesson becomes an opportunity for them to do research. Encyclopedias, science textbooks, and library books all have information about whales. For those students with access to the Internet, Web sites are also available that focus on whales. Use one of the Internet search engines to find these sites. This research may require some time to complete unless the materials have been collected prior to the lesson. After the class completes its research activities, allow the students to add new findings to the original lists of information about whales.



A whale-watching boat

Whale watching is a common tourist activity in the state of Maine. One of the intriguing things about whale watching is that individual whales have identifying features that allow avid whale watchers to identify their favorite whales. These identifying characteristics—special coloring, distinctive fins, and so on—are useful to scientists, too. It is possible to track the progress of a whale from visual sightings along its migration path.

DEVELOPING THE ACTIVITY

Materials: ***Rulers, maps of the eastern coast of the United States that include the West Indies***

Humpback whales spend April through November in the nutrient-rich waters of the northern Atlantic Ocean. The whales spend these months feeding and adding many layers of blubber. These layers of blubber provide the adult whale with nourishment for the round-trip journey between the North Atlantic and the Caribbean, where baby whales, or calves, are born. The mothers do not feed while in the quiet, warm waters of the Caribbean. The calves feed on their mother's nourishing milk to prepare them for the return journey to the North Atlantic. About March the whales begin the trip home.

This activity can be accomplished in a large group by using a class map. If several maps are available, the activity can be done in small groups. If multiple copies are made from a master map (see page 127), the students can work individually as well.

Teaching Note: ***This activity simplifies the migration path of whales. Whales actually swim in a meandering path influenced by currents in the ocean, the availability of food, and the topography of the ocean floor.***

Even in a large group, each student needs to make map measurements, record data, and perform calculations. For example, if a large classroom map is used for the activity, prepare the map for the activity by placing peel-off, self-sticking numbered dots in the ocean along the East Coast of the United States. Use enough dots, representing sightings, to trace a path for the migration from Maine to Florida as well as from Florida to the West Indies. To allow each student in the class to make a measurement on the class map, trace a return migration path with dots of a different color.

If each student can be given a map of the path of the whale, plot the migration path on a master map and make a copy for each student. Include enough data points that the migration path can easily be imagined and sketched. However, too many data points will make the activity too tedious for students to enjoy it. It is probably best to limit the path to ten or fewer data points. Since each student will make many measurements, the teacher can decide whether a different migration path is needed for the return trip. If the same data points are used under the assumption that the whale returns on a similar route, the one-way trip can be doubled to find the total distance traveled.

Have the students calculate the distances between the data points on the map. Of course, the map selected will determine the scale to be used. The following shows the calculation of the distance between two points on a map with a scale of 1 inch = 116 miles:

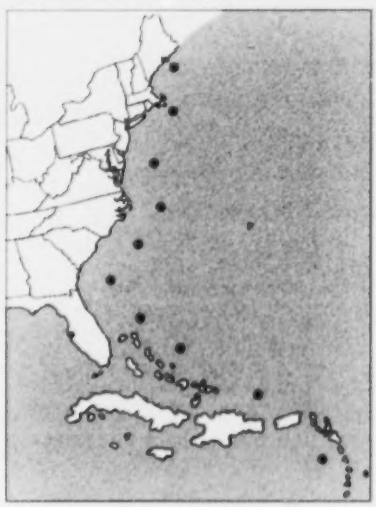
The distance between the first two sightings of the whale in the Gulf of Maine was 2 3/4 inches. How far had the whale traveled?

$$\frac{116 \text{ miles}}{1 \text{ inch}} \times \frac{2\frac{3}{4}}{1} \text{ inches} = \frac{116 \text{ miles}}{1 \text{ inch}} \times \frac{\frac{11}{4}}{1} \text{ inches}$$

$$= \frac{1276 \text{ miles}}{4}$$

$$= 319 \text{ miles.}$$

Technology Tip: ***Since the scale of the map is constant and there are repeated calculations, this activity presents an opportunity to teach students to perform constant calculations and to use the memory of the calculator to record partial sums of the distances.***



Data points on a map represent a whale's migration route.

CLOSING THE ACTIVITY

Complete all the measurements and calculations of the distances between proximate data points on the migration path. Calculate the sum of all the distances to determine the one-way distance that humpback whales migrate from the North Atlantic to the Caribbean.

Humpback whales usually complete this journey in 1 to 2 months. Of course, whales do not travel at a constant speed. However, if we know the approximate period of time used to complete the journey, an approximation of the average speed of a migrating humpback can be determined.

Assume that it takes 30 days for the trip from the Gulf of Maine to the West Indies. What is the average speed of the whale?

30 days = 720 hours.

If the calculated distance is 3960 miles, then

$$\text{distance} = \text{rate} \times \text{time},$$

or

$$\text{rate} = \frac{\text{distance}}{\text{time}}.$$

The average speed of the whale is

$$\frac{3960 \text{ miles}}{720 \text{ hours}}.$$

By dividing, we get that the average speed of the whale is 5.5 miles per hour.

The Use of Calculators: ***This is an instance in which long division with multidigit divisors is required to complete a problem. The use of a calculator allows all students to complete the problem. Having great facility with handwritten calculation is not a prerequisite to developing an understanding of dealing with equations and average rates of speed.***

Have the students calculate the average speed for the whole journey if the whale takes 36 days to complete the one-way trip.

The students should fill out a mission log sheet for this activity. Their papers showing the computations of the distances between points along the migration path and of the total distance and showing the computation of the average migration speed of the whales should be attached to the log sheet.

Part B

GETTING STARTED

Materials: ***A copy of the worksheet Thar They Blow for each student***

This activity focuses on the use of the Pythagorean theorem to calculate the approximate distance that whales may have traveled. A story about whale watching is used to stimulate the problem solving associated with finding the distance that whales have moved in a period of time.

DEVELOPING THE ACTIVITY

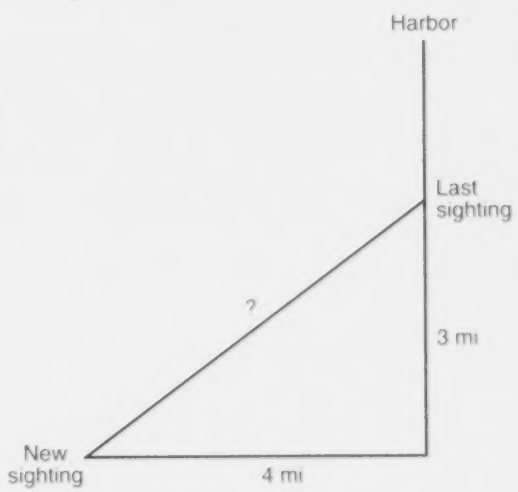
Technology Information: ***A loran (long-range navigation) unit is a navigation device that provides latitude and longitude information. This land-based system uses radio signals to help sailors, both professional and recreational, to determine their location, keep a log of important locations, and chart journeys from one point to another.***

Ask the class if anyone has had an opportunity to go whale watching. In most classes, the students will have had no experience with whale watching. Thus, it will be necessary to tell the students about going out on boats to see whales. Show the class some pictures of humpback whales and discuss how different humpback whales can be identified by distinctive coloring or scars on the flukes of their huge tails or on their side flippers.

The student worksheet for this activity uses a fictitious story about a sea captain who operates a whale-watching excursion boat. The purpose of the story is to motivate the students to calculate the approximate distance that whales travel in a short time. Some students will realize that it is unlikely that whales travel in straight lines. They meander through the water, and their path can be affected by the topology of the sea bottom as well as the availability of food. However, using straight lines allows middle school students to explore the use of the Pythagorean theorem.

Hand out a copy of Thar They Blow on page 128 to each student. Have the students read the story, and encourage them to draw the picture corresponding to the story. Remind them that on a map north is at the top, east to the right, south to the bottom, and west to the left. A sample drawing is shown at the right.

The example uses a Pythagorean triple (3, 4, 5). Another triple is used to describe a different search in the student worksheet for this activity. If students are ready to apply the Pythagorean equation $c^2 = a^2 + b^2$, where a, b, and c are rational numbers, the use of calculators is warranted. When designing new problems for the students to consider, be certain to use directions that involve right angles. Also, since the directions of the compass are integral to this activity, the students should draw pictures with the orientation of the triangle dictated by the directions given.



CLOSING THE ACTIVITY

The students should complete enough teacher-made examples to demonstrate their understanding of—

- how to compute the distance along the hypotenuse of a right triangle when the distances along the legs of the triangle are known;
- how to orient the described triangles according to the given compass directions.

The students' log sheets for this activity should give the teacher evidence of the students' understanding of both these concepts.

Some students will want to know more about how Captain Ahab knew he had traveled a certain distance on open water. A succinct answer is that the computer chip in the loran receiver on board the boat does that calculation. Global Positioning Systems also use readings from satellites to determine such distances. In the tracking of whales by satellite, transmitters are attached to whales and the satellites can "take a reading" of their position as they surface.

Part C

OPENING THE ACTIVITY

There are two concepts to be developed in this activity. The determination of a location on the globe from latitude and longitude readings is a prerequisite to thinking about the bearing from one location to another and the track of someone moving between the two locations.

Materials: ***A compass; a globe; a paper plate, a brass fastener, and two strips of index-card stock for each student; and a hand-held GPS unit (optional)***

DEVELOPING THE ACTIVITY

Open the lesson by showing the class a globe of Earth. Have the students tell what they know about the globe (number of continents, names of oceans, locations of countries, hemispheres, etc.). In some classes a student will mention the lines of longitude and latitude. If this does not occur, ask the students about the lines they can see drawn on the globe.

Map-Reading Vocabulary: ***Lines of latitude (parallels) are drawn in an east-west direction, and they provide a measure (in degrees) of the distance north or south of the equator. The equator has a latitude of 0° and the North Pole, 90°. Lines of longitude (meridians) are the north-south lines on a globe that measure the distance east or west of an arbitrarily selected meridian. This 0° meridian is known as the prime meridian. It runs from the North Pole to the South Pole through Greenwich, a town in England.***

Once longitude and latitude have been discussed, the students will need some practice in using these concepts. Spend some time having students come to the globe in pairs. Ask one student to locate a given latitude and longitude. The other student confirms or refutes the selection of the location. Next, have the second student specify a given city or other identifiable location by latitude and longitude, and have the first student confirm the reading. There will not be time for all the students to do this in a large group. To allow all the students experience with these concepts, put the globe or a world map in a learning center and have the students, in pairs, complete the activities on the worksheet on page 129 over a period of time.

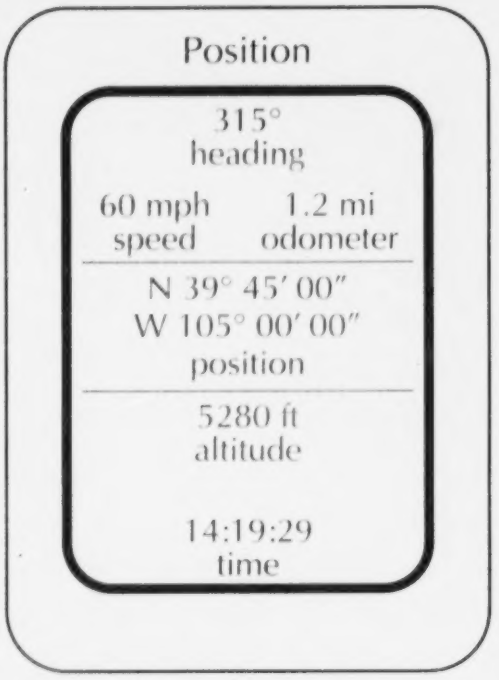
After all the students have successfully completed the learning center activity, extend their understanding of longitude and latitude by talking about the subdivisions of a degree. Degrees of longitude and latitude are subdivided into minutes, the symbol for which is ′. Each degree is composed of 60 minutes. Likewise, each minute is subdivided into 60 seconds, the symbol for which is ″. When reading a map or globe, we cannot use positions as precise as 38°28′36″ N and 78°50′08″ W for a location. We are not capable of measuring that accurately. However, the GPS satellites can help us improve our precision. Thus, when we read the position screen of a hand-held GPS unit, degrees and minutes are displayed, along with fractions of minutes that are shown as hundredths of a minute.

Obtaining GPS Navigators: ***GPS units are available in sports stores that sell hunting and fishing equipment. Stores that carry camping equipment for hikers sell them, too. Parents who enjoy these activities might share their equipment for classroom use, or they may be willing to demonstrate the units. Some sports-store employees may provide demonstrations, too.***

Curriculum Connection: Ask students, "Why is Denver known as the Mile-High City?"

Technology Information: ***The Global Positioning System (GPS) is composed of a constellation of twenty-four Navstar satellites. From unobstructed areas, at least four satellites are "in view." The computer chips in the handheld GPS units read data (position and elevation) transmissions from these satellites. A GPS receiver acquires the signal, then measures the interval between the transmission and the receipt of the signal to determine the distance between the satellite and the receiver. This process is called ranging. When the receiver calculates the range from at least three satellites, the location of the receiver on Earth can be determined. GPS devices are accurate enough for hikers, hunters, and those who fish. The readings are correct within 100 meters, or approximately 350 feet. More information on calculating the location of GPS receivers can be found in "Finding Our Way" in*** **Mission Mathematics: Grades 9–12.**

If a GPS unit can be located to use for a demonstration, show the position screen of the device. A blackline master of the picture at the right is provided on page 130. Please note that the design of GPS screens may differ slightly on different brands of receivers. However, the information will be the same.



A GPS position screen

The position screen offers more information than we are ready to use at this time. Start with the data at the bottom and work upward. The time is shown in military time. This option is found on most GPS units, but the time can be changed to the customary form. The altitude shows the height above sea level. The next information is the longitude and latitude of the location of the receiver. The top part of the screen shows data about the movement of the receiver. This movement is caused by the person carrying it. The person may be running, sitting in a moving boat or car, or riding a bicycle. Finally, there is a name for the location.

GPS units have memory. The user can store the locations of important places in the memory. These stored locations can be used to plan trips, to get from one place on a trail to another, or to locate a favorite "fishin' hole." Scientists aboard a research vessel who learn that migrating whales are located at a specific longitude and latitude can plot a course to catch up with the whales. The screens on the GPS units provide data for these types of activities.

To use the navigational screens effectively, students must be able to read a directional compass, including the degrees on the compass. Most students will be familiar with the directions on a compass. They have seen many maps in books. They realize that north is "up" and south is "down." East is to the right of the north-south line, and west is to the left. However, many students may be unaware that each of these directions is measured in degrees. Show the class a directional compass or a transparency of a simulated compass (a blackline master is furnished on page 131).

A compass

As can be seen from the drawing, north is 0°, east is 90°, south is 180°, and west is 270°. Have the students make conjectures about the measures associated with the other lines in the drawing. Be certain they understand that as north is approached by an imaginary clock hand in a clockwise movement, it gets nearer and nearer to 360°, the number of degrees in a circle.

An example of a paper-plate compass

Have the students make a paper-plate compass. This compass is made much like a paper-plate clock. The plate forms the compass, and two "hands" are attached. The hands will be added in sequence as the concepts of bearing and track are developed. The students should use scissors to make one long, narrow arrow, or needle. This needle should be attached to the paper plate at the middle with a brass fastener. The students should indicate the degree measures at the appropriate points on the compass for 0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315°.

Obtaining a Compass: ***Many classes will include at least one Boy Scout or Girl Scout. Some of these students may be able to make a presentation about the compass. The leisure activity of orienteering involves the use of a compass. Orienteering compasses, as well as basic ones, are available from outdoor stores at a reasonable price.***

Navigation Vocabulary:

Bearing: ***the intended direction that a person must travel to reach a specified destination***

Track, or course: ***the actual direction that a person is traveling***

Once the paper-plate compasses have been constructed, the students can practice moving the needle to settings described by the teacher in degrees. Once the students are placing the compass needle correctly, look at another of the screens—the pointer, or navigation, screen—on the GPS unit or the facsimile on page 132.

Most information on the pointer screen is similar to that on the position screen. The concepts of bearing and track (course) are the key notions in this activity. Notice that the half compass in the center of the pointer screen has two pointer arrows, one for the bearing and another for the track. Have the students add the second arrow to the paper-plate compass. This arrow should be shorter and heavier than the first one. The following example illustrates a use of the bearing and track information given on a pointer screen.

Suppose that a whale researcher using satellite readings has located a pod of whales somewhere in the distance. The latitude and longitude of the pod are saved. Since the researcher wants to study the whales, the pointer screen is selected. The captain reads the bearing of the pod (293°) and wants to set the track (course) of the ship in that direction. First he notes the bearing of the pod on his compass.

The next task of the captain is to read the track (course) of the boat and turn the proper direction and amount so that the bearing and track are the same. When he looks at the GPS unit, the pointer screen reads as shown at the left.

Use the paper-plate compass to show both the bearing and the track for these data. The long hand should show the track and the shorter one the bearing, just as the arrows on the pointer screen do. How many degrees is the ship off course? Should the captain turn left or right?

Use the Bearings and Tracks worksheet on page 133 to practice what you have learned about bearing and track.

A GPS pointer screen

EXTENDING THE LESSON

The GPS poster in the *Mission Mathematics: Grades 9–12* materials extends the ideas in this lesson. Some students will realize that

determining track and bearing is a dynamic situation. Each time the wind or current moves the boat off course, the captain must correct the track. Some of the poster activities may help the students begin to think about this idea. Other GPS activities can be found in Nord, Jabon, and Nord (1997).

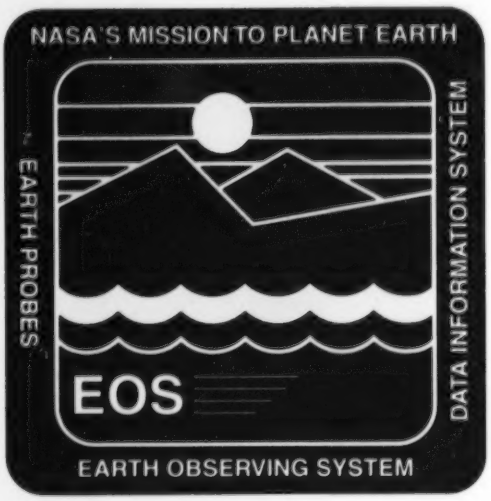
CLOSING THE ACTIVITY

The mission log sheets should be completed to close the activity. Since the students have completed three activities for this lesson, it would be appropriate for them to write about the science, geography, and mathematics involved in the entire experience. The theme of this lesson is ideal for an interdisciplinary unit. As a part of the language arts portion of the interdisciplinary unit, students might be asked to develop a public-service announcement about whales and their migration or technology-minded students might be challenged to design a World Wide Web page to display information about migrating whales.

This is a time to ask students to do some additional research on other scientific activities involved in NASA's Mission to Planet Earth. Ozone depletion, deforestation, air pollution, ocean temperatures, and many other exciting areas of research are supported by NASA scientists and laboratories. These topics, too, can be the basis for interdisciplinary units in which mathematics can be learned in a meaningful and motivating context.

Deforestation has three major environmental effects: (1) it reduces the planet's ability to absorb carbon dioxide; (2) it influences local weather and climate, especially precipitation and water-storage patterns; and (3) it reduces biodiversity.

MISSION TO PLANET EARTH



Date: _____

Mission Specialist's
Name: _____

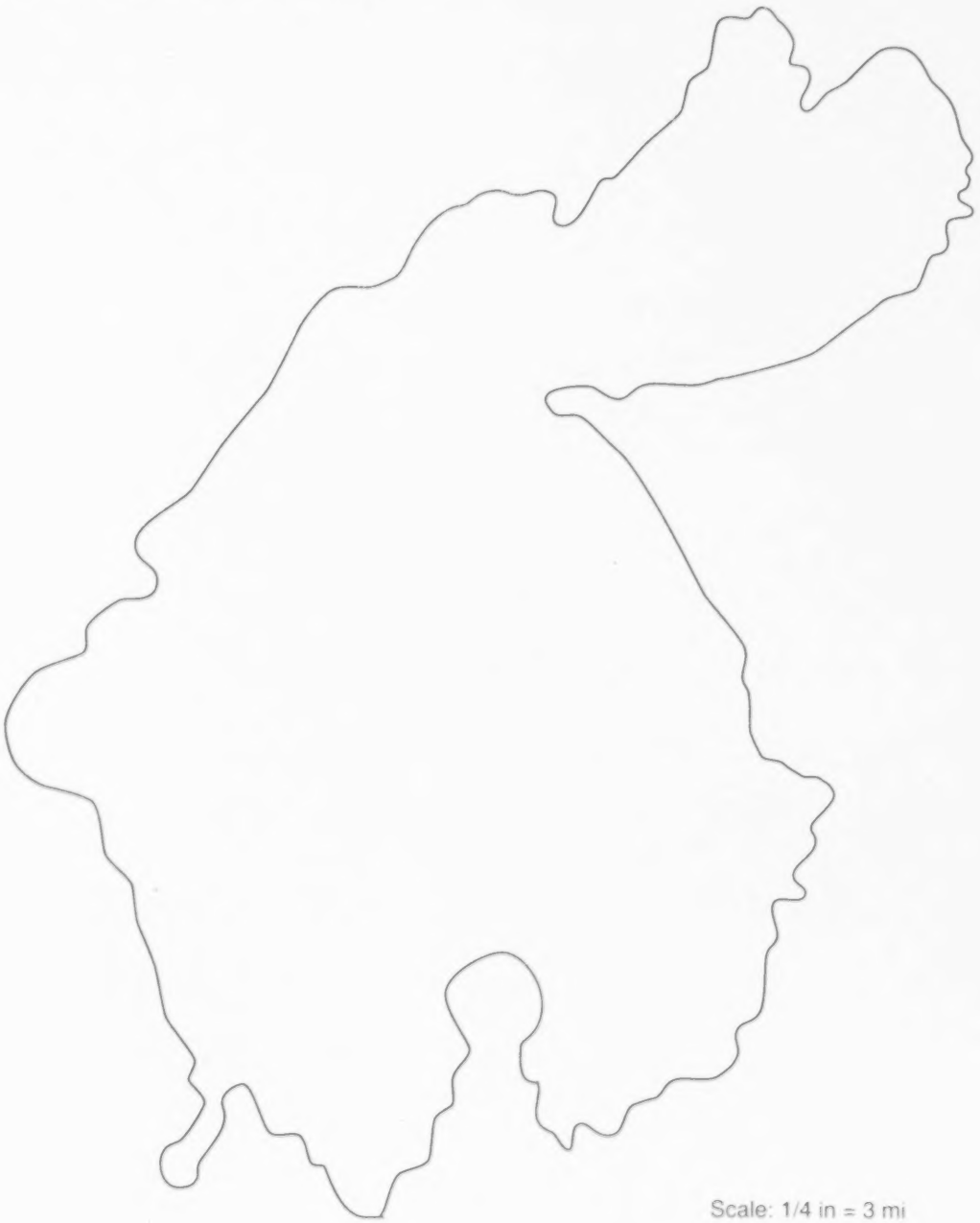
The things I did and the mathematics I used:

The things I found out and the mathematics I learned:

The things I wonder about and the mathematics I want to know about:

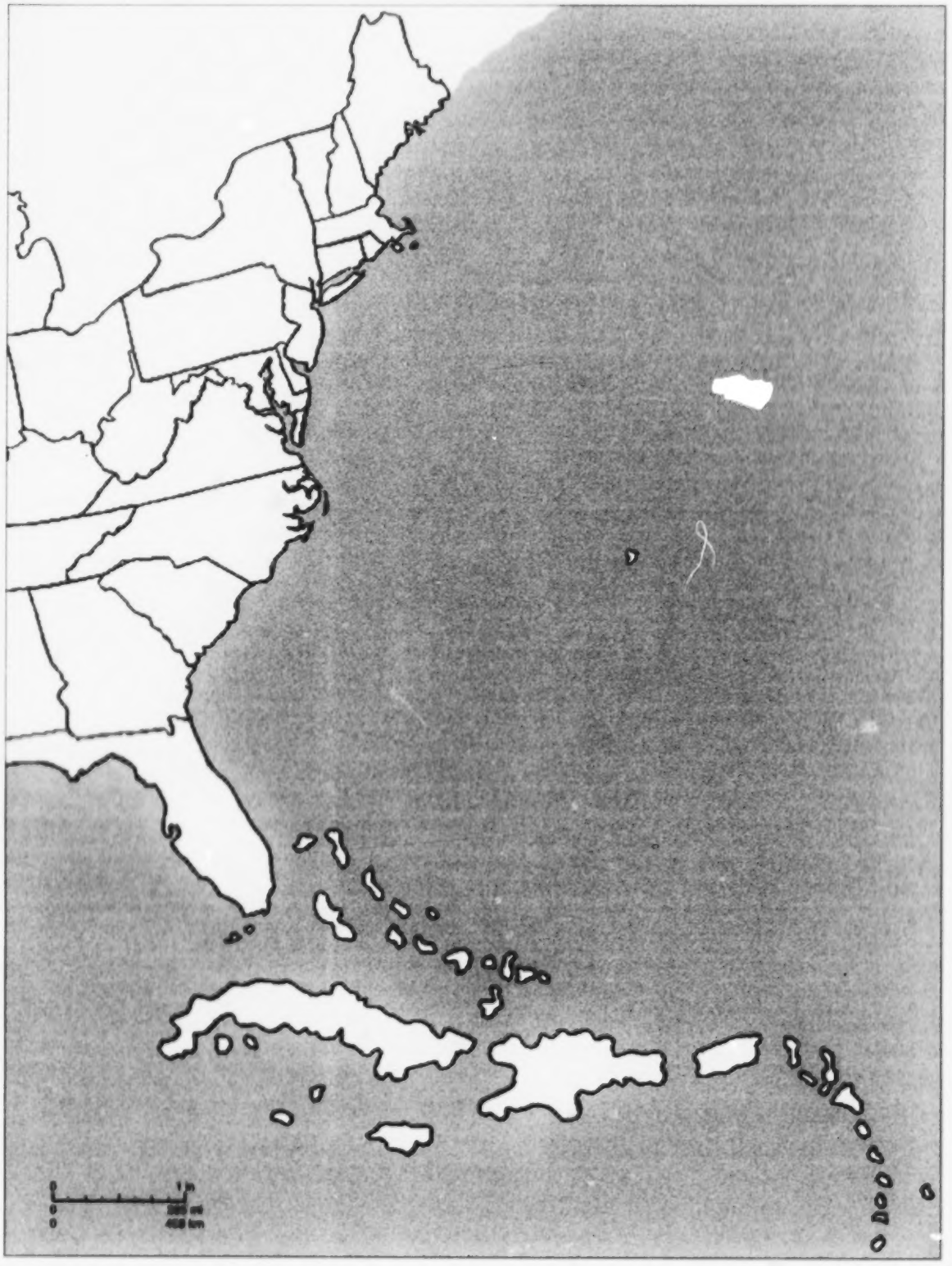
ICE MASS

Determine the area of the ice mass represented by the scaled figure below.



Scale: 1/4 in = 3 mi

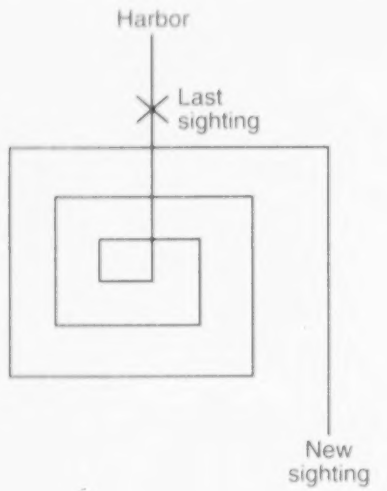
U.S. EAST COAST AND WEST INDIES



THAR THEY BLOW

Captain Ahab, a Maine sea captain, has a whale-watching boat, the *Acadia*. He takes passengers out for half-day or whole-day excursions to see humpback whales. The key to his success is that Captain Ahab almost always finds whales for his passengers to see. He uses his knowledge of whale behavior and his loran (*lo*ng-*ra*nge *n*avigation) unit to locate whales. He listens to his radio, too. Often other boats will use a ship's radio to tell others of whales sighted.

On an excursion Captain Ahab uses the loran receiver to look for locations where he has seen whales recently. He knows the location of the dock. He uses this location and the location of a recent sighting to determine an initial course to follow. If he arrives at a loran-marked site and there are no whales, he searches in a pattern. He begins by sailing south for a specified distance, then turns west for a time, then north, and finally east. Of course, he cannot turn sharply enough to make a right-angle turn, but he tries his best to do so. He hopes to produce a search pattern of an ever widening "right angle" spiral (see the illustration below).



One afternoon Captain Ahab went south from the harbor to look for the humpbacks where he had seen them on the morning excursion. Alas, the whales had moved. He began his usual search pattern. He had traveled 12 miles to the south from the point of the morning sighting when he heard a radio message from a boat that had seen the whales. After a conversation with the radio operator on the other boat, he found that they were due west of the *Acadia*. Captain Ahab turned the boat 90 degrees clockwise and proceeded to the location. They traveled 5 miles and located the whales. How far had the whales traveled since they were last seen by Captain Ahab?

Draw a picture of the course that Captain Ahab followed to find the whales, and use the data to calculate the straight-line distance the whales traveled.

LATITUDE AND LONGITUDE

Activity 1

Work in pairs. The first partner selects one of the locations below. Using the given latitude and longitude, the second partner points to the location on a map or globe and identifies the major city near it. The first partner then checks the work (the names of the cities are given at the bottom of the worksheet). When the second partner has identified two locations correctly, reverse roles. Repeat the exercise until all the locations have been identified.

1. 28° N, 97° W
   What Texas city is near this location?
2. 40° N, 105° W
   What Colorado city is near this location?
3. 42° N, 71° W
   What Massachusetts city is near this location?
4. 28° N, 82° W
   What Florida city is near this location?
5. 40° N, 120° W
   What Nevada city is near this location?
6. 35° N, 90° W
   What Tennessee city is near this location?
7. 21° N, 158° W
   What city is near this location?
8. 15° N, 121° E
   What capital city is near this location?
9. 35° S, 58° W
   What capital city is near this location?
10. 34° S, 18° E
    What seaport city is near this location?

Activity 2

Work in pairs. The first partner points to a city or an important landmark on a map or globe. The second partner identifies the latitude and longitude of the city or landmark. The first partner then checks the work and accepts answers that are within 5° of the actual latitude and longitude. Reverse roles after the second partner has correctly identified two locations. Repeat the exercise until all the locations have been identified.

The following are some examples of cities and landmarks:

1. Washington, D.C.
2. Hong Kong
3. The Eiffel Tower
4. The Kennedy Space Center
5. Cleveland, Ohio
6. Niagara Falls
7. Bar Harbor, Maine
8. Marquette, Michigan
9. Dallas, Texas
10. Phoenix, Arizona
11. Pierre, South Dakota
12. Victoria Falls (Africa)

Activity 3

Work in pairs. Use your map skills to answer the following questions:

1. Part of what state is north of 60° N?
2. What city in the mainland United States is closest to the equator?
3. What is the longitude of the easternmost point in the mainland United States?
4. What state reaches farther than 170° W?
5. Follow the 40° N latitude line from the East Coast of the United States to the West Coast. What major cities lie close to this latitude?

Answers

Activity 1: 1. Corpus Christi; 2. Denver; 3. Boston; 4. Orlando; 5. Reno; 6. Memphis; 7. Honolulu; 8. Manila; 9. Buenos Aires; 10. Cape Town. **Activity 2:** 1. 39° N, 77° W; 2. 22° N, 114° E; 3. 49° N, 2° E; 4. 28° N, 81° W; 5. 42° N, 82° W; 6. 41° N, 79° W; 7. 44° N, 68° W; 8. 47° N, 87° W; 9. 11° N, 97° W; 10. 11° N, 112° W; 11. 44° N, 100° W; 12. 17° S, 26° E. **Activity 3:** 1. Alaska; 2. Key West; 3. Approximately 67° W; 4. Alaska; 5. Some examples are Philadelphia, Pennsylvania; Columbus, Ohio; Indianapolis, Indiana; Springfield, Illinois; and Denver, Colorado.

Position

315°
heading

60 mph
speed

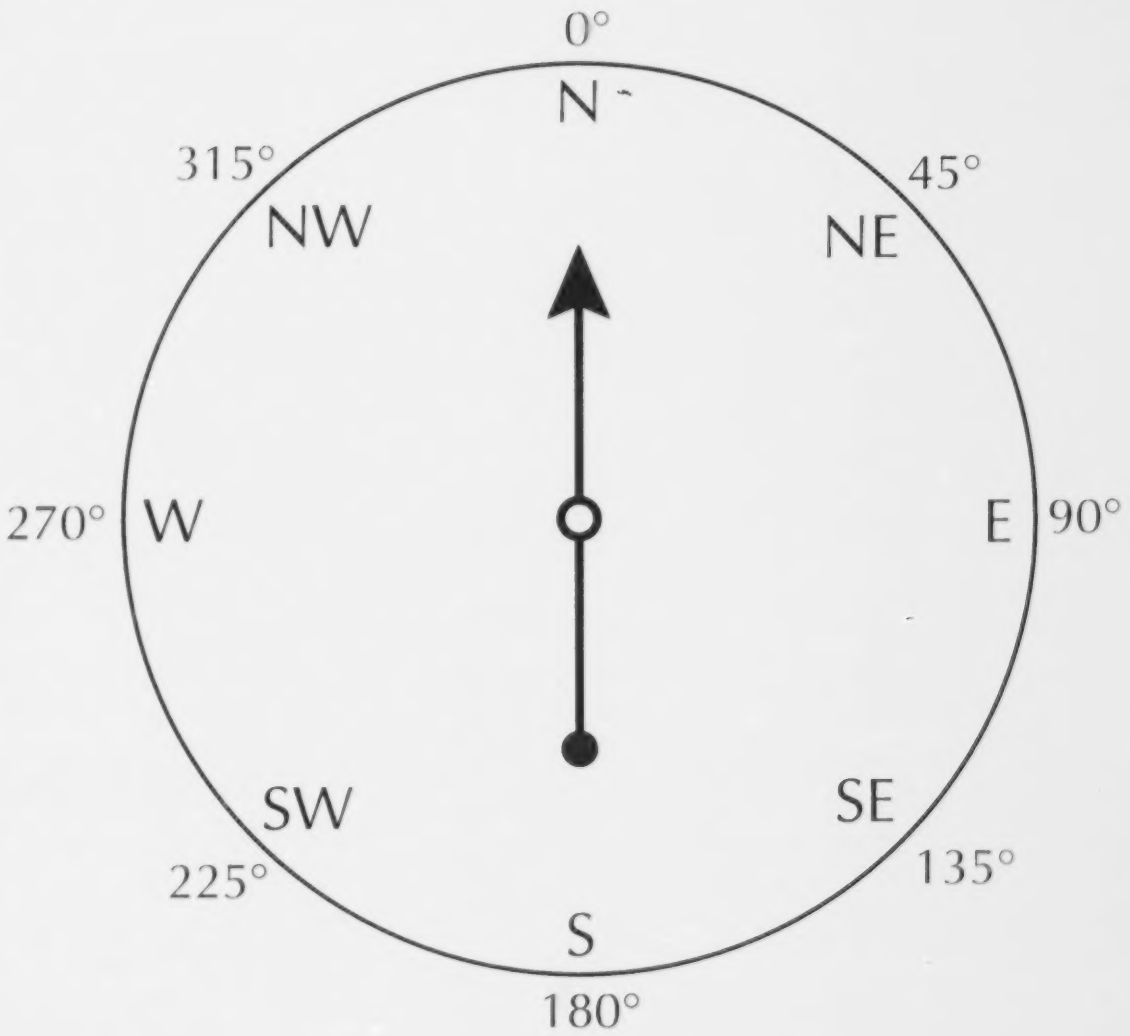
1.2 mi
odometer

N 39° 45′ 00″
W 105° 00′ 00″
position

5280 ft
altitude

14:19:29
time

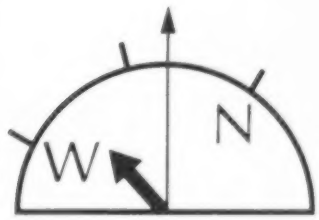
COMPASS



Navigation

293°
bearing

4.2 mi
distance



332°
track

8.6 mph
speed

07:49:45
time

BEARINGS AND TRACKS

Mission Specialist's
Name: _____

Use your paper-plate compass to help you set the following bearings on the pictures of compasses provided. Show your answer on a paper-plate compass to a classmate near you. When you agree that the answer is correct, draw the arrow on the illustration.

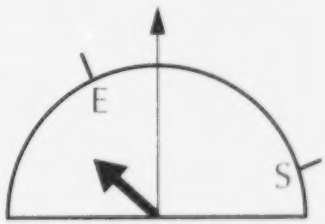
1. Bearing: 60°

2. Bearing: 275°

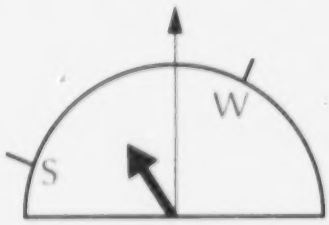
3. Bearing: 155°

4. Bearing: 340°

In the illustrations below, the track is shown by the longer arrow and the bearing is shown by the shorter arrow. Look at each illustration. Normally, ships' captains make the shortest turn to align the bearing and track. Tell whether you, the ship's captain, would turn left or right to make the track and bearing become the same.



_____



_____

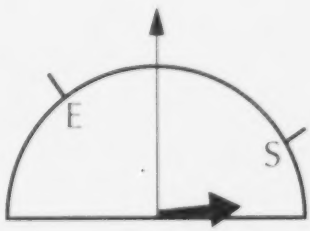
Below are several compasses with bearings shown. Estimate the number of degrees shown by each of the illustrations.

1. Bearing: _____

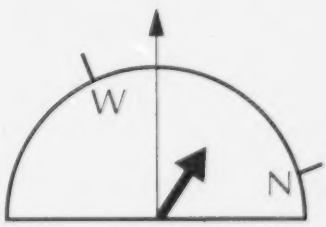
2. Bearing: _____

3. Bearing: _____

4. Bearing: _____



_____



_____

APPENDIX
NASA RESOURCES FOR EDUCATORS

NASA's Central Operation of Resources for Educators (CORE) was established for the national and international distribution of NASA-produced educational materials in audiovisual format. Educators can obtain a catalog and an order form by one of the following methods:

- NASA CORE
  Lorain County Joint Vocational School
  15181 Route 58 South
  Oberlin, OH 44074
- Phone (216) 774-1051, ext. 249 or 293
- Fax (216) 774-2144
- E-mail nasaco@leeca8.leeca.ohio.gov
- Home Page: http://spacelink.msfc.nasa.gov/CORE

Educators Resource Center Network

To make additional information available to the education community, the NASA Education Division has created the NASA Educators Resource Center (ERC) network. ERCs contain a wealth of information for educators: publications, reference books, slide sets, audio cassettes, videotapes, telelecture programs, computer programs, lesson plans, and teacher guides with activities. Teachers may preview, copy, or receive NASA materials at these sites. Because each NASA Field Center has its own areas of expertise, no two ERCs are exactly alike. Phone calls are welcomed if you are unable to visit the ERC that serves your geographic area. A list of the centers and the regions they serve is at the left.

Regional Educators Resource Centers (RERCs) offer more educators access to NASA educational materials. NASA has formed partnerships with universities, museums, and other educational institutions to serve as RERCs in many states. A complete list of RERCs is available through CORE, or electronically through NASA Spacelink.

NASA On-line Resources for Educators provides current educational information and instructional resource materials to teachers, faculty, and students. A wide range of information is available, including science, mathematics, engineering, and technology education lesson plans; historical information related to the aeronautics and space program; current status reports on NASA projects; news releases; information on NASA educational programs; and useful software and graphics files.

Access these resources through the NASA Education Home Page: www.hq.nasa.gov/education.

Quest is the home of NASA's K–12 Internet Initiative, one of the electronic resources that the agency has developed for the educational community. The project specializes in providing programs, materials, and opportunities for teachers and students to use NASA resources as learning tools to explore the Internet. Through Quest, teachers can access information about educational grants, interact with other schools that are already online, and explore links to other NASA educational resources.

One of Quest's most unusual endeavors is the "Sharing NASA" online interactive project. Students and educators are given the opportunity to communicate with NASA scientists and researchers to experience the excitement of real science in real time. In addition to these programs, the project also houses information about materials that accompany the K–12 Internet Initiative videos. These videos promote the Internet in schools and assist educators in acquiring and integrating the Internet into the classroom (for information about the videotapes, send an e-mail message to video-info@quest.arc.nasa.gov).

AK, AZ, CA, HI, ID, MT, NV, OR, UT, WA, WY
NASA Educators Resource Center
Mail Stop 253-2
NASA Ames Research Center
Moffett Field, CA 94035-1000
Phone: (415) 604-3574

CT, DE, DC, ME, MD, MA, NH, NJ, NY, PA, RI, VT
NASA Educators Resource Center
Mail Code 130.3
NASA Goddard Space Flight Center
Greenbelt, MD 20771-0001
Phone: (301) 286-8570

CO, KS, NE, NM, ND, OK, SD, TX
NASA Educators Resource Center
Mail Code AP2
NASA Johnson Space Center
2101 NASA Road One
Houston, TX 77058-3696
Phone: (281) 483-8696

FL, GA, PR, VI
NASA Educators Resource Center
Mail Code ERC
NASA Kennedy Space Center
Kennedy Space Center, FL 32899-0001
Phone: (407) 867-4090

KY, NC, SC, VA, WV
Virginia Air and Space Museum
NASA Educators Resource Center for NASA Langley Research Center
600 Settlers Landing Road
Hampton, VA 23669-4033
Phone: (757) 727-0900 x 757

IL, IN, MI, MN, OH, WI
NASA Educators Resource Center
Mail Stop 8-1
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135-3191
Phone: (216) 433-2017

AL, AR, IA, LA, MO, TN
U.S. Space and Rocket Center
NASA Educators Resource Center for NASA Marshall Space Flight Center
P.O. Box 070015
Huntsville, AL 35807-7015
Phone: (205) 544-5812

MS
NASA Educators Resource Center
Building 1200
NASA John C. Stennis Space Center
Stennis Space Center, MS 39529-6000
Phone: (601) 688-1200

Serves requests related to space and planetary exploration
NASA Educators Resource Center
JPL Educational Outreach
Mail Stop CS-530
NASA Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109-8099
Phone: (818) 354-6916

CA (cities near the center)
NASA Educators Resource Center for NASA Dryden Flight Research Center
P.O. Box 273
45108 North 32nd Street East
Lancaster, CA 93535
Phone: (805) 948-7347

VA and MD's Eastern Shore
NASA Educators Resource Center
Education Complex - Visitor Center
Building E-1
NASA Wallops Flight Facility
Wallops Island, VA 23337-5099
Phone: (757) 824-2297/2298

Quest can be accessed on the Internet at http://quest.arc.nasa.gov. To stay informed about new oppportunities in the Sharing NASA program, send an e-mail message to listmanager@quest.arc.nasa.gov. In the body of the message, write these words: subscribe sharing-nasa. For additional information, send an e-mail message to info@quest.arc.nasa.gov.

NASA Spacelink is one of NASA's electronic resources specifically developed for use by the education community. This comprehensive electronic library contains current and historical information related to NASA's aeronautics and space research. Teachers, faculty, and students will find that Spacelink offers not only information about NASA programs and projects but also teacher guides, pictures, and computer software that can enhance classroom instruction.

Spacelink also provides links to other NASA resources on the Internet. Educators can access materials chosen specifically for their educational value and relevance, including science, mathematics, engineering, and technology education lesson plans; information on NASA educational programs and services; current status reports on agency projects and events; news releases; and television broadcast schedules for NASA Television.

Spacelink can be accessed at the following address: spacelink.nasa.gov. For additional information, e-mail comments@spacelink.msfc.nasa.gov.

NASA Television (NTV) features Space Shuttle mission coverage, live special events, interactive education videoconferences, electronic field trips, aviation and space news, and historical NASA footage. Programming has three blocks—Education File, History File, and News Video File—repeated at intervals 24 hours a day.

The Education File features programming for teachers and students on science, mathematics, and technology. Teachers and their classes can investigate exciting NASA research endeavors in aeronautics, microgravity, planetary sciences, human exploration of space, Earth systems, robotics, and more. Educators are welcome to videotape from NTV.

Tune in to NTV by GE-2 satellite, transponder 9C at 85 degrees west longitude, vertical polarization, with a frequency of 3880 megahertz (MHz) and audio of 6.8 MHz, or through collaborating distance-learning networks and local cable providers.

For more information on NTV, contact NASA TV, NASA Headquarters, Code P-2, Washington, DC 20546.
Phone: (202) 358-3572

The brochure *How to Access NASA's Education Materials and Services*, EP-1996-11-345-HQ, serves as a guide to accessing a variety of NASA materials and services for educators. Copies are available through the ERC network or electronically through NASA Spacelink.

REFERENCES

Blackburn, Ken, and Jeff Lammers. *The World Record Paper Airplane Book*. New York: Workman Publishing Co., 1994.

National Aeronautics and Space Administration. *Spinoff 1993*. Washington, D.C.: National Aeronautics and Space Administration, 1993.

———. *Spinoff 1994*. Washington, D.C.: National Aeronautics and Space Administration, 1994.

———. *Spinoff 1995*. Washington, D.C.: National Aeronautics and Space Administration, 1995.

National Council of Teachers of Mathematics. *Assessment Standards for School Mathematics*. Reston, Va.: National Council of Teachers of Mathematics, 1995.

———. *Curriculum and Evaluation Standards for School Mathematics*. Reston, Va.: National Council of Teachers of Mathematics, 1989.

———. *Professional Standards for School Mathematics*. Reston, Va.: National Council of Teachers of Mathematics, 1991.

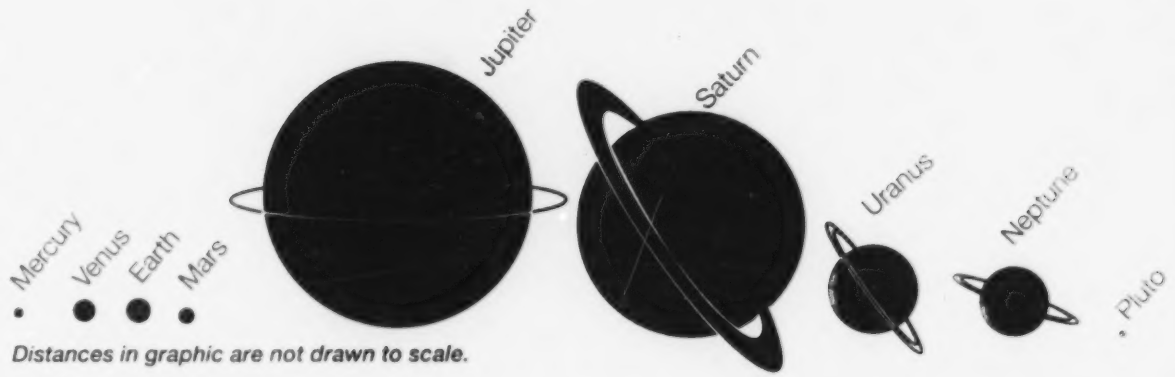
Nord, Gail D., David Jabon, and John Nord. "The Mathematics of the Global Positioning System." *Mathematics Teacher* 90 (September 1997): 455–60.

Schmidt, Norman. *Best Ever Paper Airplanes*. New York: Sterling Publishing Co., 1994.

Young, Mark C. *Guinness Book of World Records*. Stamford, Conn.: Guinness Media, 1996.

Taking a Spin around the Solar System

The Planets at a Glance



Distances in graphic are not drawn to scale.

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Mean Distance from the Sun									
Millions of Kilometers	57.9	108.2	149.6	227.9	778.3	1 427	2 871	4 497	5 913
Millions of Miles	36	67.2	93	141.5	483.3	886.2	1 782.9	2 792.6	3 672
Period of Rotation (in Earth time)	58.9 days	243 days*	23 h, 56 min	24 h, 37 min	9 h, 55 min	10 h, 40 min	17 h, 12 min*	16 h, 7 min	6.39 days*
Inclination of Orbit to Ecliptic	7°	3.4°	0°	1.85°	1.3°	2.5°	0.8°	1.8°	17.1°
Equatorial Diameter									
Kilometers	4 880	12 100	12 756	6 786.8	143 200	120 000	51 800	49 528	~2 300
Miles	3 031	7 514	7 921	4 215	88 927	74 520	31 168	30 757	~1 447
	0	0	1	2	16	18+ (?)	15	8	1

* Retrograde rotation

Plotting Planetary Paths

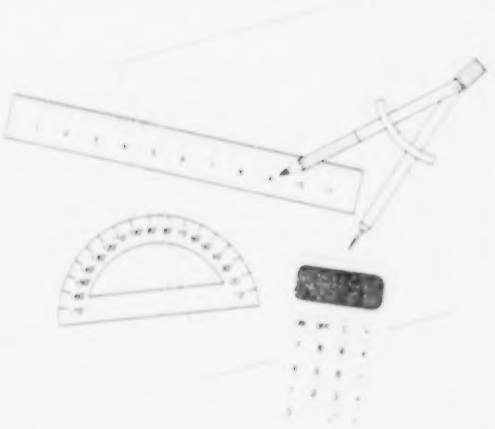
The solar system is so vast that it is difficult to create a picture of the entire system that will show the relative sizes of the planets *and* keep the distances between them proportional to their actual distances. In this activity, you will study two planets (Earth and one other planet) and make a diagram showing their relative positions as they move around the Sun.

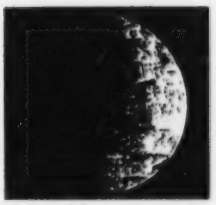
With your model, you will be able to investigate questions such as these:

1. Would a person on Earth view the other planet at night?
    - Always
    - Sometimes
    - Never
2. What is the maximum distance between these two planets? Minimum distance?
3. In a month, how much do Earth and the other planet move around the Sun?

Tools Needed

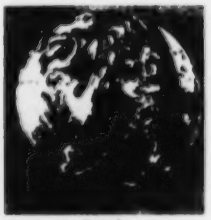
- Ruler
- Compasses
- Protractor
- Paper
- Calculator or computer spreadsheet





Mercury

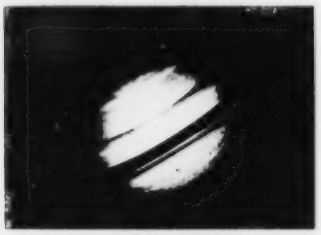
Venus



Earth

Mars

Jupiter



Saturn

Uranus

Neptune

Pluto

Preliminary Figures

In order to make the distances in your model proportional to the actual distances, you'll need to do some preliminary calculations. Use the data in The Planets at a Glance chart to help you set up the scale for your model.

The general proportion below can help you establish distances for your model.

$$\frac{\text{Actual distance}_1}{\text{Actual distance}_2} = \frac{\text{Model distance}_1}{\text{Model distance}_2},$$

where distance$_1$ refers to Earth-related distances and distance$_2$ refers to distances related to the other planet you choose.

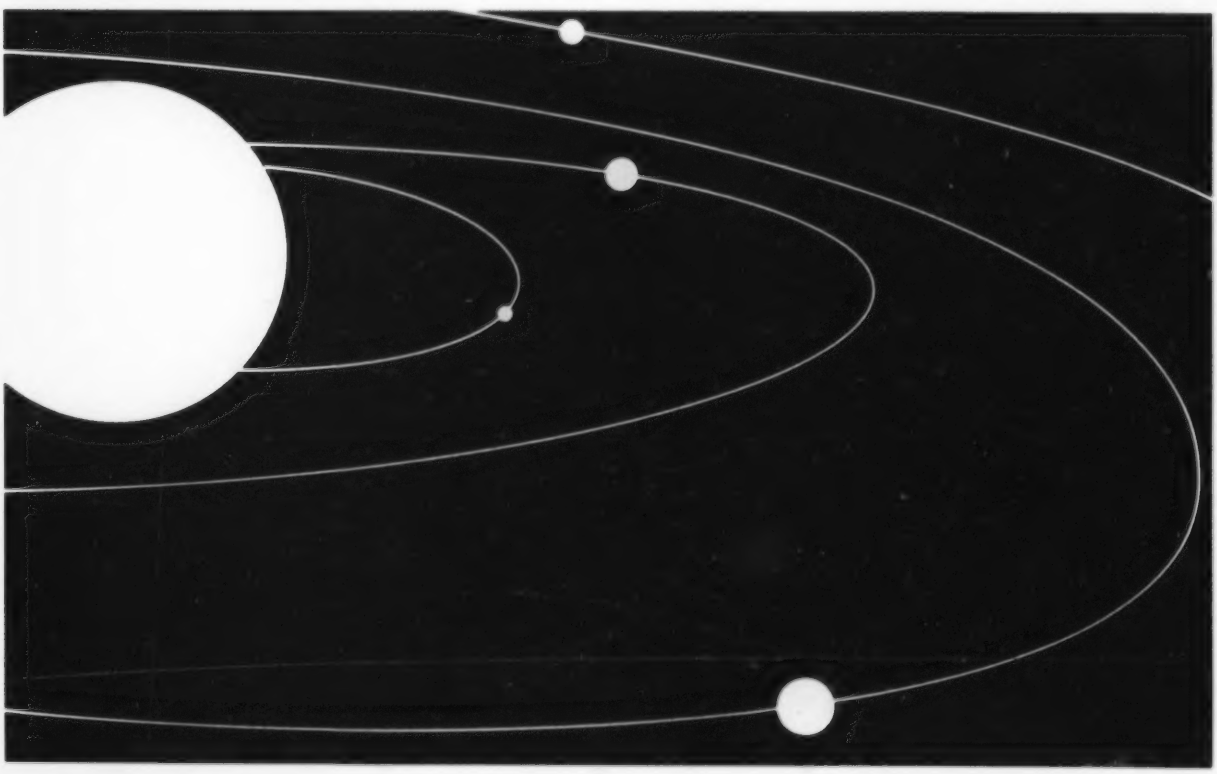
In order to show the positions of the planets as they move about the Sun, you'll need to divide the total orbit into units representing some constant unit of time—say, weeks, months, or years.

Decide on the unit of time that you will use on the basis of the periods of revolution for the two planets you're investigating.

You can use a proportion to determine the number of degrees of arc that each planet will travel in that unit of time:

$$\frac{\text{Unit of time chosen}}{\text{Time for a complete revolution}} = \frac{\text{Degrees of arc traveled in one time unit}}{360}$$

If your chosen unit of time results in less than 5° of arc, you may want to try a larger unit of time to simplify your model.



Assumptions

For this activity, you can assume that the orbits of the two planets are coplanar and are circles, although the orbits of the planets are not quite circular. The data show that Pluto and Mercury have the greatest amount of variance between the closest and the farthest that their orbits take them with respect to the Sun. For the other planets, the difference between their paths and a circle is so small that it will not make a big difference in your findings.

Your model will be taking numbers that represent millions of kilometers and representing them with lengths that are just a few centimeters. Because of that, you should be using approximate figures that will be easy to work with.

Since you do not know the actual position of the planets, your model will need to assume a starting point on the orbit of each planet. From that point you can show the relative positions at each time unit.

Plotting the Orbits

Once you have the distances established for your scale model, you can model the orbits of your two planets by constructing circles, using the Sun as the center of both circles.

Plotting the Movements of the Planets

Once you have the orbits and starting points for each planet, you can use a ruler and a protractor to trace the movements of those planets along their orbits. Remember to set up proportions that will relate each planet's movements to a portion of the circle (in degrees).

Completing the Investigations

After you have plotted the movements of both planets, you can analyze their movements to respond to the three investigations suggested in the Plotting Planetary Paths panel. You should write up your responses to each investigation, explaining your conclusions and how you arrived at those conclusions.

Additional Investigations

- How fast (km/h) is each of your planets moving around the Sun?
- Plot the path that a space probe might take from Earth in order to intercept your other planet.

It can be seen, after a certain amount of time, that there is a difference between the distances that planets travel around the Sun.

Aeronautics

Aeronautics

The illustration on the other side of this poster depicts four stages in the development of aircraft: concept, design, modeling, and testing.

Stage 1: Concept

Clients identify the purpose for which the airplane will be used, for instance, transporting passengers, transporting goods and equipment, conducting research, engaging in aerial combat, and monitoring weather conditions. With designers, they decide what features are required to accomplish that purpose—speed, maneuverability, fuel economy, capacity, and so forth.

Collect pictures of airplanes that serve different purposes.

Stage 2: Design

Aeronautical engineers who specialize in specific fields of engineering study the requirements and propose designs for the airplane. Their designs incorporate the features that would both serve the purpose of the airplane and take into account such real-world constraints as time and budget. The following are four important design considerations:

- **Aerodynamics**—the flow of air around the vehicle
- **Propulsion**—the type of engine and the power requirements
- **Materials and structure**—the types of materials used in constructing the airplane and the relationships among its major components
- **Stability and control**—the handling of the airplane in flight

In the pictures you have collected, identify the features in the airplanes that were designed specifically to help them accomplish their mission.

Stage 3: Modeling

Scale models of the proposed design are constructed. Modern computer technology can be used to produce blueprints and three-dimensional representations of the vehicle and its components.

Design and make a paper airplane for a specific purpose, for instance, to stay aloft for a long time, to do loops, or to fly a great distance.

Stage 4: Testing

Testing is done at each stage of the design. By careful computation, design concepts are checked and the soundness and suitability of structures and materials are verified. Wind-tunnel tests measure aerodynamics, and flight simulations evaluate control and stability. Test flights of prototypes are the final step before mass production and commercial use.

Test-fly the paper airplane you designed and those designed by other students. Does your plane excel in the aspect of performance for which you designed it?

Aerodynamics

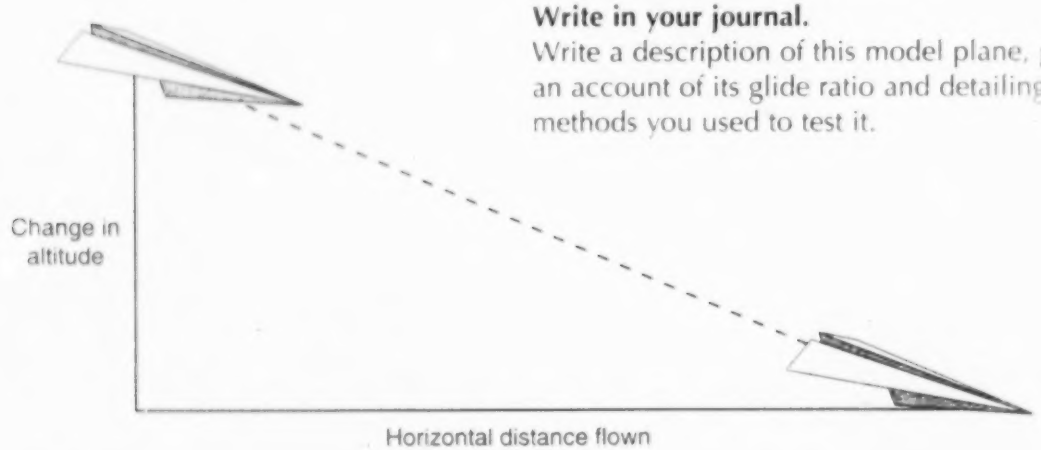
What would happen to an airplane if it suddenly lost its power? Would it drop like a rock? Would it glide for a while? How far could the pilot expect it to fly before reaching the ground?

Glide Ratio

The glide ratio of a plane helps to answer questions like these. It describes the horizontal distance that the plane will travel from a given altitude in the absence of power and wind.

$$\text{Glide ratio} = \frac{\text{Horizontal distance flown}}{\text{Change in altitude}}$$

The glide ratio is usually expressed as a negative number, since the change in altitude is a loss of altitude and is therefore expressed as a negative distance.



Experiment 1

Make a model airplane that you think will stay aloft and glide a long distance even with a very light toss.

Set up an area to conduct test flights.
You might use a length of cord, marked off in meters or feet, anchored to a "starting line." Be sure to launch your plane from a constant height for each trial in your experiment.

Test-fly your plane.
Conduct a minimum of ten test flights. Be as consistent as possible in the force you use to launch the plane.

Analyze the data and determine the glide ratio.
Look at the distances flown for each of your test flights. Put these distances in order. Find the shortest distance. The longest distance. The median distance. The mean distance. For each of these distances, compute the glide ratio. Which of the glide ratios that you have computed is the "best" one to use in describing your plane's glide ratio? Be ready to explain why you chose the one you did.

Write in your journal.
Write a description of this model plane, giving an account of its glide ratio and detailing the methods you used to test it.

Structure

Air moving under an airplane's wings give it lift. It might seem that having larger wings would help a plane stay in the air longer. This experiment will let you test that idea (hypothesis).

Experiment 2

Determine the ratio of the area of the wings to the total surface area.
Begin this experiment by determining how much of your airplane's total material is devoted to its wings. We can use surface area to find the ratio of the material in the wings to the total material in the plane. Unfold your airplane. Determine the total area of the paper.

Next, measure each of the smaller areas that help to form the wings of your plane. Calculate the ratio of the areas:

$$\frac{\text{Area of wings}}{\text{Total area of paper}}$$

This ratio can be used to test the hypothesis.

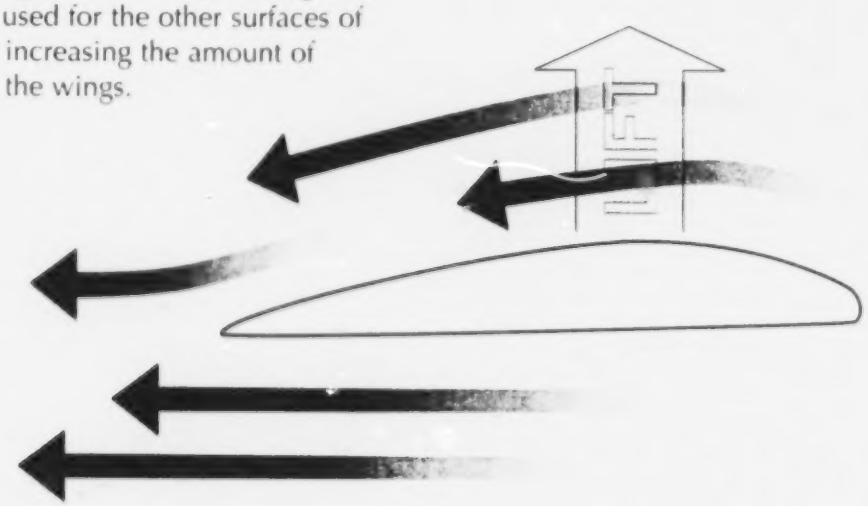
Increase the ratio.
Modify the design of your plane to increase the size of the wings. You will be reducing the amount of paper used for the other surfaces of the structure and increasing the amount of material used for the wings.

Gather and analyze data for the modified design.
Test-fly your new design to see if your modifications have increased the glide ratio. Conduct experiment 1 using your new design. Plotting the data for both planes can help you analyze the effects of your redesign.

Compare your findings with other students' results.
If other students in your class have been conducting similar experiments, you can exchange data to see whether their results support the hypothesis that the relative size of a plane's wings influences its glide ratio.

Suggestion: A scatterplot can be an effective way to analyze this kind of data.

Write in your journal.
Write a report of your work on this experiment. Do your findings support the hypothesis?



Planning a Flight

Depending on an airplane's altitude when it loses its propulsion, the pilot can expect to glide a certain distance before landing. The higher the plane was when it began to glide, the farther the pilot can expect to travel before touching down.

Experiment 3

In this experiment, you will use the data that you've already collected to make some predictions about flights begun from other altitudes. You will also test the hypothesis that the glide ratio of the paper airplane will not change if it is launched from a different height.

Do the mathematics.
If the glide ratio of a paper airplane does not change, then the following proportion will hold true:

$$\frac{\text{height}_1}{\text{distance}_1} = \frac{\text{height}_2}{\text{distance}_2}$$

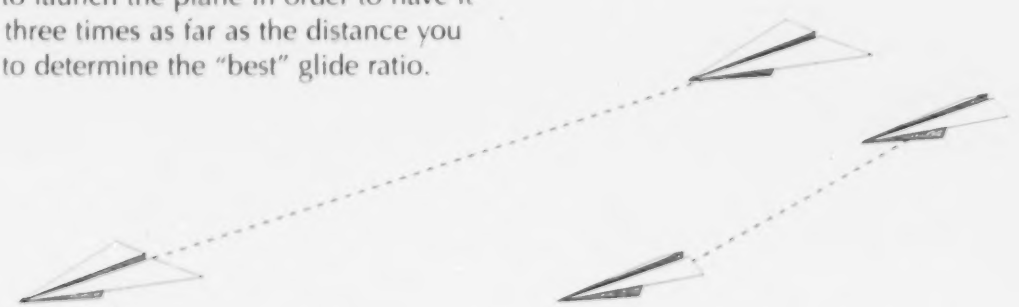
Substitute for height_1 the height you used as a launch height in experiment 1. Substitute for distance_1 the distance that you used to determine the "best" glide ratio.

- How far would you predict the plane would glide if it were launched from a height twice your experimental height?
- Predict the height from which you would have to launch the plane in order to have it glide three times as far as the distance you used to determine the "best" glide ratio.

Verify the hypothesis.
Determine a launch height that you can reach by standing on a stairway or another safe platform. You will need to be able to determine the height and the glide distance, so plan this part of your experiment carefully.

Conduct experiment 1 again from this new height. Find the glide ratio of the plane from this launch height. Compare your data with the original data you collected in experiment 1. Is the glide ratio the same?

Write in your journal.
Write up the findings from this experiment. Be sure to tell if your data support the hypothesis.



International Space Station

International Space Station

The illustration on the other side of this poster depicts the International Space Station in its completed and fully operational state with elements from the United States, Europe, Canada, Japan, and Russia. The Space Shuttle transports three scientist-astronauts on a rotating basis to relieve some of the crew already aboard the International Space Station. On the return trip, the Shuttle transports the replaced astronauts to Earth.

Also shown on the poster are scenes from the production of several components of the Space Station and a look at the Shuttle as it might be used during the construction of the Space Station.

Facts and Figures

End-to-end width (wingspan)	356.4 feet (108.6 meters)
Length	262 feet (79.9 meters)
Mass	1 005 021 pounds (456 629 kilograms)
Inclination	51.6 degrees to the equator
Atmosphere	14.7 pounds per square inch 101.36 kilonewtons per square meter (same as Earth)
Crew size	Up to 7 persons

Getting It Up There

The Space Station will be assembled from parts brought into orbit by the Space Shuttle and Russian transports. The panel at the right gives information about the payload capacities of the Space Shuttle.

Using that information, estimate the number of Shuttle missions that would be needed to bring all the pieces into orbit.

Assembly

Getting the parts of the International Space Station into orbit and assembling them into a livable facility will take several years, starting in 1998. Consider some facts and figures about the Space Shuttle to get an idea of the scope of this task.

Space Shuttle

Wingspan	23.79 meters
Length	37.24 meters
Height	17.27 meters
Payload bay	18.3 meters × 4.6 meters
Payload weight (launch max.)	24 948 kilograms

Activity 1

Make a scale drawing of the payload bay of the Shuttle, using these figures. Using that drawing and the figures shown in the panel at the left, design a typical Space Station module.

- What shape would your module have?
- What dimensions would it have?
- How much space would the astronaut-scientists have to work in?

The Typical Space Station Module...

is a cylindrical shell about 28 feet long and 14.5 feet in diameter. It is fitted with racks that form four walls about 7 feet wide (remember that in space, the "floor" and "ceiling" serve as usable wall space).

The space between the four walls and the outer shell can be filled with equipment, supplies, and other materials necessary for the station to support life (see the illustration below).

Activity 2

Make another scale drawing showing a cross section of your module design. This time, include the compartments that would hold the experiments, the supplies, and the equipment that will be needed in space.

- What percent of your total space is devoted to room for the astronauts?
- What percent would hold equipment and supplies?
- Is there any space remaining?
- What use(s) might it have?

Power

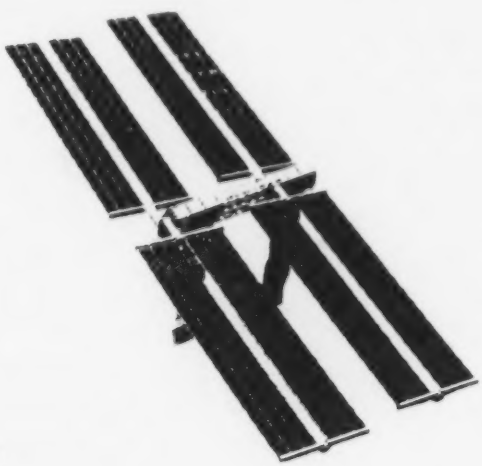
The primary source of power in the International Space Station will be a large array of solar panels that can be moved to track the position of the Sun. This will maximize the amount of solar energy that the panels will be able to transfer to storage cells on the station.

The total area of the solar panels planned for the International Space Station is about 1 acre. They will provide about 112 kilowatts of power for every 90-minute orbit.

Activity 3

A square mile covers exactly 640 acres. If you have an electronic calculator, it probably has a small solar panel that is used to provide power to the calculator. Suppose that you were going to take all the calculators in your classroom, remove the little solar cells, and then put them together to form a larger solar panel.

- What would the total area be?
- What portion of the Space Station's solar panels would be equal to your total panel?
- About how much power would your solar panel generate in 90 minutes?



Water

One of the essential supplies on the International Space Station is water. On Earth, people in the United States use about 160 gallons of water a day on average. This includes water used for sanitary purposes, cooking, manufacturing, and so on. In the Space Station, each astronaut will be alotted about 2.6 gallons of water a day for drinking and personal hygiene combined. Most of that water will be recycled.

Suppose that the crew of six has enough water for a six-month mission (including a safety reserve that will enable them to survive for a full year in case of trouble).

Activity 4

Assume that 90 percent of the water is recycled each day.

- How much water should be brought on board at the start of the mission?
- How much will that water weigh?
- How much space will the water take up in the station?

(Consult a dictionary or encyclopedia to find the weight and volume of a gallon of water.)

Protection

The outer skin of the modules on the International Space Station contains a debris shield, several layers of insulation, and a waffled pressure wall. The total thickness of the outer wall is about 1/40 of the station's diameter. By contrast, Earth's protective layer (made up of the troposphere, stratosphere, and mesosphere) is only 1/160 of Earth's diameter.

Activity 5

Assume that the diameter of a module on the International Space Station is 13 feet.

- How thick would the wall of the module be?
- How deep is Earth's protective layer?

Communication

The Space Station will transmit data to Earth at the rate of 43 million bits per second as it travels in orbit an average of 253 miles above Earth at about 17 500 miles per hour.

Activity 6

Use the facts above to get a sense of how much data the station will be sending to Earth and how fast and far it is traveling.

- How long would it take to transmit the information found in your mathematics textbook? (*Hint:* Figure out the average number of characters on a page. One bit is the same as one character.)
- How long will it take the station to orbit Earth one time?
- How many miles will the astronauts travel in one six-month mission?

A cross section of the Space Station with astronauts working

MISSION MATHEMATICS: GRADES 5–8

National Council of Teachers of Mathematics

90641
9 780873 534352

641